This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

NGIN. LIB.
TD
225
S97
A25
1889

A 757,493 DUPL

ENGIN. LIBRARY
TD
225
.S97
A25
1889

REPORT

OF

COMMISSIONERS

ON

SOURCES OF WATER SUPPLY

FOR THE

CITY OF SYRACUSE,

NEW YORK.

FEBRUARY 1st, 1889.

1889.

THE ENGINEERING & BUILDING RECORD PRESS,
82-84 FULTON ST., NEW YORK.

Syracuse, N.Y. Commission on sources of water supply 31507

REPORT

OF

COMMISSIONERS

ON

SOURCES OF WATER SUPPLY

FOR THE

CITY OF SYRACUSE,

NEW YORK.

FEBRUARY 1st, 1889.

1889.

THE ENGINEERING & BUILDING RECORD PRESS,
82–84 FULTON ST., NEW YORK.

TABLE OF CONTENTS.

I.—Commissioners' Report.

	PAGE.
Introduction	7
Quantity of Water Obtainable	9
Quality of Water	11
Method of Distribution	17
General Features of Plan for Bringing Water from Skaneateles Lake	18
Cost of Construction	19
Rights of the State to Waters of Skaneateles Lake	21
Constitution of 1822, Article 7, Section 10	22
Availability and Present Value of Works of Syracuse Water Company	23
City Ownership	23
Conclusions and Recommendations	24
Statement of Expenditures—Exhibit A	25
List of Maps and Profiles and Engineers' Note Books accompanying Report of Commissioners—Exhibit B	25
List of Engraved Maps and Diagrams Accompanying Engineer's Report	27
Chapter 532, Laws of 1888, State of New York	27

II.—Report of J. J. R. Croes, C. E.

Scope of Investigations 1
Quantity of Water Required 2
Description of Sources of Supply—
Salmon River 3
Skaneateles Lake 4
Lake Ontario 7
Seneca River 8
Onondaga Creek at Cardiff 8
Tully Lakes 9–17
Ground Water from Gang Wells 11
Cazenovia Lake 14
Oneida Lake 14
Otisco Lake 15
Syracuse Water Company's Works 17
Chapter 224, Laws of 1849 21
Quality of Water—
Analyses by Professor Cornwall 23
Analyses by Dr. Harrington 27
Analyses by Professor Waller 30
Interpretation of Analyses 34
Diagram of Results of Analyses 40
Biological Examination by Dr. Currier 42
Conclusions as to Quality of Waters 49
Ownership of Works by City or Company 50
Availability and Value of Existing Works of Syracuse Water Company 53
Estimates of Cost of Proposed Projects 54
Estimates of Complete Works 57
Table of Location of Water Mains in City 58
Table of Location of Hydrants in City 60
Methods of Analysis and Cost of Softening Water, by Prof. H. B. Cornwall 67

I.—REPORT OF COMMISSIONERS.

REPORT OF THE COMMISSIONERS.

To the Honorable

The MAYOR and COMMON COUNCIL of the CITY OF SYRACUSE.

GENTLEMEN:—On the 21st day of June, 1888, we the undersigned, were appointed by the Mayor to constitute a Board of Special Commissioners to inquire into and investigate the sources of water supply for the City of Syracuse, pursuant to Chapter 532 of the Laws of 1888.

It is made the duty of this Board "to inquire into and investigate the several sources of a water supply which may be made available for the public, mechanical and domestic uses of said city. Such investigation shall have regard to the abundance of the supply of water and its quality and character; and in case they shall determine to recommend for adoption by the city any source of supply which they shall have investigated, or any system or plan for the distribution of water throughout the city, they shall prepare a detailed plan for the construction of works therefor including the location of reservoirs, and shall make and report to the Common Council an estimate of the cost of such construction, showing distances of transportation, and whether the water will be supplied to all parts of the city by gravitation or otherwise. They shall also inquire into the availability of the present water-works in said city as a part of such system which they may recommend and an estimate of the present value thereof, and shall include the same in their report, which shall be transmitted to the Common Council together with their recommendations on or before the 10th day of January, 1889, when all books and papers relating to such investigation, and all property belonging to said city in the possession or under the control of said Special Commissioners shall be deposited by them in the office of the City Clerk of said city to be disposed of as the

Common Council may direct." By an act of the Legislature approved on the 10th day of January, 1889, the time for filing the report of the Commissioners was extended to February 1st, 1889.

Pursuant to our appointment we respectfully submit the following report:

We met at the City Hall on the 22d day of June, 1888, upon the appointment of the Mayor, and each Commissioner having duly qualified as prescribed by the act aforesaid, said Board was organized by electing Mr. E. B. Judson, Chairman, and Mr. James B. Brooks, Secretary. Notice of such elections was immediately transmitted to the Mayor, Common Council, and the Treasurer of the City of Syracuse. On the 17th day of July, 1888, we entered into engagement with Mr J. J. R. Croes, C. E., of New York City, to take charge of the investigation to be made by the Board. The personal character and professional standing of Mr. Croes are so well established and so generally recognized that we consider ourselves and the citizens of Syracuse fortunate in having been able to secure his services.

Mr. Croes, upon the approval of our Board, designated and employed Mr. W. R. Hill, C. E., as his assistant. The work we are able to present with this report will itself best attest the wisdom of this selection. But for the ability, industry and fidelity of Mr. Hill in prosecuting his part of the work, we could scarcely have compassed the task assigned us in the time at our disposal.

A detailed statement of the expenses incurred by the Board is appended hereto, and marked Exhibit "A."

We file herewith, as required by the act aforesaid, all maps and documents prepared by us in the course of our investigation, and turn over herewith all documents and property in our possession belonging to the city: and a detailed schedule thereof is appended hereto and marked Exhibit "B."

On entering upon the discharge of our duties we determined that if possible at a reasonable expenditure, a water supply should be secured which would be ample for all the needs and purposes of the city and its inhabitants for a period of at least fifty years; the water of such quality as to be suitable for all public, mechanical and domestic purposes—domestic purposes being considered by

us of primary importance—to be supplied by gravitation to all parts of the city. We believed nothing less would satisfy the people, and that our growth and prosperity as a city were largely dependent thereon.

At a meeting of our Board July 17, 1888, after careful consideration, we determined to confine our investigations to the following alleged sources of water supply, which we believed comprised all that could in any way be regarded as practicable for supplying the City of Syracuse, viz.:

1. Salmon River.
2. Skaneateles Lake.
3. Lake Ontario.
4. Seneca River.
5. Onondaga Creek at Cardiff.
6. Gang Wells.
7. Cazenovia Lake.
8. Oneida Lake.
9. Otisco Lake.
10. Tully Lakes.
11. Supply of Syracuse Water Company.

Such investigation was commenced about the middle of July, 1888, and has been prosecuted to completion under the direction and supervision of Mr. Croes, by Mr. Hill and other assistants.

The result of such examination and investigation is embodied in the report of Mr. Croes which is hereto annexed. From all the information that we are able to obtain, and after a careful study of such report, we accept the statements therein and base our conclusions and recommendations thereon.

Quantity of Water.

It is estimated that the city will increase in population for the next ten years at the average rate of 5,500 per annum, which will make the population of the city in 1899 145,000; that for the next following ten years the increase will average 7,000 per annum, and after that 8,000 per annum; that the supply of water cannot safely be reckoned at less than eighty gallons daily per capita; that the source should be sufficient to supply the city for a period of fifty years; and therefore should be capable of fur-

nishing 37,000,000 gallons daily. The water-works first to be constructed should be capable of delivering a sufficient supply of water for a period of fifteen years; that is, the first works constructed should be able to deliver at least 15,000,000 gallons daily to the city.

It is estimated that one square mile of water-shed can be depended upon in this vicinity to furnish on an average 600,000 gallons per day. From these figures it is concluded that any sufficient source of supply must possess at least sixty square miles of tributary water-shed.

Cazenovia Lake has a water-shed of nine square miles; and the Tully Lakes of 13.72 square miles. Therefore neither of these sources alone is capable of furnishing the city with sufficient water.

The Onondaga Creek at Cardiff has a water-shed of about forty square miles, and can be relied upon to furnish only from 25 to 30 millions per day. But the Tully Lakes can readily be rendered tributary to this source, and the quantity of water increased thereby to 37 or 38 million gallons per day.

Otisco Lake has a water-shed of forty-two and a half square miles, and can furnish about the same quantity of water as the Onondaga Creek at Cardiff; the State uses this lake as a reservoir for supplying the Erie Canal.

The Gang Wells in Onondaga Valley we are forced to believe, from the result of tests and examinations made, are incapable of furnishing a sufficient supply, or, in fact, any considerable quantity of water for any great length of time. We refer to the report of Mr. Croes at pages 11 to 14 for a detailed statement of the examinations made under his supervision.

Salmon River has a water-shed above the proposed reservoir of seventy square miles; Skaneateles Lake, including the area of the lake, of seventy and one-fourth square miles; Oneida Lake of 1,327 square miles, and the water-shed of Seneca River above Baldwinsville is sufficient.

It is apparent, therefore, that of all the alleged practicable sources of supply, only Salmon River, Skaneateles Lake, Oneida Lake, Onondaga Creek at Cardiff coupled with the Tully Lakes,

Lake Ontario and Seneca River, are capable of furnishing an ample supply of water for a period of fifty years.

Quality of Water.

The quality of water to be furnished is of such importance, and is so closely related to the subject of the health and comfort of the people, and the development of the city's interests, that we have sought with great care the best attainable information on the question of the quality of the waters of all the alleged available sources of supply.

To the ordinary observer, Skaneateles Lake would appear more desirable for domestic purposes than any other source. It is a body of water fifteen miles long and about one mile wide, with an area of twelve and three-quarters square miles. It is very deep throughout, its shores are abrupt, free from vegetable growth at the water's edge, and the lake is not connected with swamps or marshes. The water is supplied from springs in the lake or on the adjacent hillsides. It is clear and sparkling in appearance, has no color, and is comparatively free from all danger of contamination, there being not to exceed 180 dwellings nearer than one-half mile from the shore of the lake, except the village of Skaneateles, which is situated at the outlet, and cannot be regarded as an objection to this source of supply. Actual use and experience have demonstrated that for drinking purposes it is pleasant and wholesome, and is entirely suitable for all domestic purposes.

About 85 per cent. of the Salmon River water-shed is wooded, and is likely so to remain for half a century to come. The water must, therefore, in certain seasons of the year, contain a large amount of decaying vegetable matter, and in all probability would be injuriously affected by impounding. It is slightly colored, certainly not equal in appearance to the water of Skaneateles Lake; and it seems to us that the character of the water-shed of this source of supply is such as to make it undesirable.

Seneca River "is sluggish for long distances, passing through extensive marshes, and the population on the drainage area is too dense to permit any hope of procuring good water from the river," even if other conditions were favorable.

Oneida Lake water-shed presents some conditions that must exert a great influence upon the quality and character of the water of the lake. The lake is about twenty miles long and four and a half miles wide. Its mean depth is twenty feet, its greatest depth sixty feet. It is comparatively a shallow lake. The beach is flat. The rise and fall of the water is about ten feet, which leaves a large area exposed in time of low water. A large portion of the streams that flow into the lake are sluggish and must drain many of the numerous flourishing villages that stand upon the drainage area. The water-shed contains 18,000 dwellings and includes a part of the city of Rome. The appearance of the water is not good, its temperature is high, it contains a large amount of growing vegetable matter and living organisms. These facts seem to be sufficient to exclude this source of supply.

The water-shed of Onondaga Creek at Cardiff, and the Tully Lakes, appears to us more satisfactory than that of Salmon River or Oneida Lake. It contains little or no swamp or marsh lands, and the water is less liable to contamination. The water is of a lower temperature than that of Oneida Lake, and is much better in appearance.

We say then, judging from the character of the water-sheds and streams tributary thereto, and the appearance and general features of the water, that Skaneateles Lake would seem to be by far the most desirable source of water supply.

Further to satisfy ourselves in regard to the quality of the water of the different sources, Mr. Croes with our approval, caused analyses and examinations of the waters of all the available sources to be made by Prof. H. B. Cornwall, of the John C. Green School of Science at Princeton, New Jersey; Dr. Charles Harrington, of Boston, who has had large experience as one of the analysts of the State Board of Health of Massachusetts; Professor Elwyn Waller, of the School of Mines, Columbia College, analyst for the New York City Board of Health, and Dr. C. G. Currier, of New York City, an expert of large experience in the biological examination of waters.

The result of these examinations is made a part of Mr. Croes's report.

The names of these eminent men we believe to be a sufficient guarantee of the quality of their work, and its great value in the settlement of the problem submitted to this Board and to the City of Syracuse, in connection with the water supply question. We do not deem it needful to reproduce here the entire analyses mentioned. Inserted between pages 32 and 33 of Mr. Croes's report is a summary of the several chemical analyses, and at page 43 is a table showing the result of the biological examination.

By a careful study of their reports it will be found that the analysts reached somewhat different conclusions, and it would seem that it is often difficult to determine solely by chemical analysis the suitableness of water for domestic purposes. The gentlemen selected to make the examinations stand in the front rank of their profession, and could have no other purpose than to ascertain the exact facts in respect to the different samples of water examined. Professor Cornwall says in his report, speaking of the water of Salmon River: "It does not seem to be one of the most desirable samples." Dr. Harrington says: "The sample from Salmon River, with proper storage, appears to be, on the whole, the best for all purposes of a public supply." Professor Waller states the properties of the water of Salmon River are such that it should be excluded from consideration.

Professor Cornwall states that the water of Oneida Lake "is not a bad water as regards organic purity, but it is somewhat doubtful in that respect. The impurity may be only of vegetable origin, but even in that case its extent is such that the possible variations in amount at different times of the year should be carefully studied before adopting it as a general supply." Dr. Harrington says of the same water that "it can hardly be considered as a good water on account of the amount and character of the organic matter. It is possible, however, that this water would improve with storage." Professor Waller, in his report, places this water as next to Skaneateles Lake for sanitary and domestic uses. Dr. C. G. Currier states that he considers the water of somewhat doubtful quaility from the possibility of contamination, and places it third in rank.

Speaking of the water of Onondaga Creek at Cardiff, Professor Cornwall states that "organically it is of very fair quality, decidedly better than constitutes the supply of many of our largest cities. The hardness is great, but not such as to preclude its use even in its present condition. For special purposes the hardness could easily be reduced to a very moderate amount by the use of lime. Dr. Harrington says it is very free from organic matter, but has considerable hardness, which, from both a domestic and manufacturing standpoint, is an objection. Professor Waller says that "sewage contamination is apparently absent from this water; that it might be used for domestic purposes, although the hardness is considerable and on the extreme limit allowed for use in boilers," and for sanitary and domestic uses he classes this water as third. Dr. Currier states that, from a biological examination, this water seems to present more chance of dangerous contamination than any of the waters available, and is of doubtful quality.

While this difference of opinion exists in respect to the quality of the water from the sources mentioned, all the analysts agree that the waters of Lake Ontario, Seneca River, the Gang Wells, and the present city supply, are entirely unsuitable for domestic purposes, the last two sources for mechanical purposes as well; and they also all agree that the water of Skaneateles Lake is entirely satisfactory in this regard. Professor Cornwall states in his report that a chemical analysis of this water shows it to be organically quite pure for a lake water; the moderate hardness is nearly all due to carbonate of lime, and could if necessary for special purposes be greatly reduced by the judicious use of lime. Dr. Harrington says that he would consider the water of Skaneateles Lake as very fair for domestic and manufacturing purposes. Professor Waller says that the water of Skaneateles Lake is of good quality, both for domestic and manufacturing purposes. For sanitary and domestic uses he places this water first. Dr. Currier states that he considers the water of Skaneateles Lake by all means the best.

Soft water, free from any considerable amount of sulphates is most desirable for use in boilers and for manufacturing purposes; water best adapted to sanitary and domestic purposes

must be pure and free from any constituents that may produce or foster disease, and sufficiently soft to be usable for laundry purposes. These are vital points in the subject matter submitted to us, and to overlook or disregard any of them would render our labor of little value if not calamitous to the city.

The following standards as to the quality of water we believe to be trustworthy, viz.: A water that exceeds sixteen parts in 100,000 parts in total hardness is undesirable for use; a water that contains an excess of 1.0 part of chlorine, or .015 part of albuminoid ammonia in 100,000 parts is unsafe, and .010 of albuminoid ammonia is suspicious.

The several chemical analyses of the various waters show an average as to hardness as follows (the figures represent parts in 100,000):

	Total Hardness.	Total Solids.
Gang Wells	43.32	79.800
City Water-Works	36.41	54,850
Onondaga Creek	24.30	43.000
Cardiff	17.02	23.433
Seneca River	14.50	30.700
Lake Ontario	12.45	24,834
Green Lake	10.80	16.400
Oneida Lake	9.53	15.067
Skaneateles Lake	9.17	13.033
Otisco Lake	8.05	13.450
Salmon River	2.97	6.367

The three chemical analysts agree in excluding the first two sources above named from consideration on account of hardness and the amount of sulphates contained. Onondaga Creek water (taken near the wells) must also be excluded under the standard given. The water at Cardiff is, to say the least, on the very limit permitted; but it is said of this water that the carbonates predominate and much of the hardness can be removed by the use of lime. The facts, we believe, bring this water so far as its hardness is concerned within the limit of a suitable water.

As to those constituents which are deemed harmful to the health of the people, the chemical analyses give us the following results, the table being re-produced from page 39 of Mr. Croes's report (the figures represent parts in 100,000):

	Free Ammonia.	Albuminoid Ammonia.	Chlorine.
Gang Wells	0.0028	0.0031	3.023
City Water-Supply	0.0040	0.0035	1.850
Cardiff	0.0033	0.0043	0.362
Onondaga Creek, near wells	0.0050	0.0070	0.600
Skaneateles Lake	0.0035	0.0080	0.353
Green Lake	0.0160	0.0120	0.500
Salmon River	0.0127	0,0149	0.206
Otisco Lake	0.0057	0.0163	0.330
Lake Ontario	0.0035	0.0175	3.837
Oneida Lake	0.0049	0.0185	0.290
Seneca River	0.0140	0.0210	4.300
Suspicious Standard, more than	...	0.0100	....
Dangerous Standard, more than	...	0.0150	1.000

Accepting the above figures and the standards given, we must exclude the Gang Wells, the City water supply, Lake Ontario and Seneca River, on account of the amount of chlorine their waters contain ; Salmon River, Otisco Lake, Lake Ontario, Oneida Lake and Seneca River, on account of the excess of albuminoid ammonia. This leaves only Skaneateles Lake and the Cardiff valley to be accepted as furnishing suitable water for domestic and sanitary purposes.

In this connection we refer to the statement of the result of Dr. Currier's biological examination at page 43. As to the value of this examination, Mr. Croes says (p. 42): "While this (examination) does not, any more than chemical analysis, determine the absolute wholesomeness of a water, in the absence of any recognized disease-producing bacteria, scientists affirm that, 'other things being equal, richness in bacteria indicates organic impurity, scarcity of bacteria, organic purity.' If, however, there are a large number of bacteria of only a few species, and those not recognized as dangerous, and the chemical analysis shows purity, the water may be considered safe, but at the same time as more liable to pollution than a water equally pure chemically, in which few bacteria are found."

Dr. Currier says (p. 47): "Although a large number of living bacteria need not in itself give sufficient ground for pronouncing a water objectionable, still the fewer bacteria present the nearer is the water to the ideal of excellence."

No known method of analysis is infallible, but we believe the analyses presented, when taken in connection with such other facts as are known to exist in the case of each of the several waters, will lead us to safe conclusions. Exposure to possible or probable contamination is an important element in the problem ; a water may appear well under a chemical analysis, and yet well known exposure to contamination should lead to a condemnation of the water unless satisfactory protection can be afforded.

We conclude from the result of the examinations made, from our observation of the various waters and the character of the water-sheds of the several sources of supply, and from all the information which we have been able to obtain, that the water of Skaneateles Lake is the best obtainable for all the uses and purposes of the city of Syracuse. In our opinion in point of excellence it is all that can be desired, and equal in every respect to the water supply of any city in the State.

Next to Skaneateles Lake, but decidedly below it in point of excellence, as a source of water supply for the city, must be placed Onondaga Creek at Cardiff, used in connection with the Tully Lakes.

Method of Distribution.

Practically there are only two ways in which water can be distributed to all parts of the city—

1. Gravitation, by which water may be conveyed from its natural source to a distributing reservoir at a sufficient elevation above the level of the city to supply all without mechanical aid.

2. By pumping water from a given source into such distributing reservoir.

Of the two methods we are of the opinion that, independently of the question of cost, the gravity system is preferable. Insurance companies recognize this fact, and have established a less rate for insurance, other things being equal, in those cities which are supplied with water by gravitation. This system is based on natural laws and is less liable to interruption or failure.

Of the sources of supply considered available, from only two can the water be distributed to all parts of the city by gravitation —namely, Skaneateles Lake and Salmon River. In our opinion

in this regard Skaneateles Lake is preferable to Salmon River, for the reason that the length of the pipe line to a distributing reservoir from Skaneateles Lake would be seventeen miles; whereas, it would be 42 miles from Salmon River, which would greatly increase the chances of accident and interruption of the supply.

GENERAL FEATURES OF PLAN FOR BRINGING WATER FROM SKANEATELES LAKE.

The elevation of the surface of the water of Skaneateles Lake above the Syracuse level of the Erie Canal is 463 feet. It is proposed to take the water from the east shore of the Lake, and from a point at such distance therefrom as to make it entirely certain that it will be free from pollution. A line of 30-inch cast-iron pipe to be laid from the lake in the valley of Skaneateles Creek for a distance of 3½ miles; thence deflecting to the right in a north-easterly direction, passing over Earl's Summit, and crossing the head-waters of Carpenter's Brook to the steep sloping ground known as the Alps, on the Auburn branch of the New York Central and Hudson River railroad; thence adjacent to and south of the railroad to Camillus Station; thence following a valley along the Genesee turnpike in substantially a straight line, to the proposed distributing reservoir site, to be located on Knapp's Hill, 2½ miles west of the centre of the city, and 17 miles—following the pipe line—from the lake. The site of the distributing reservoir is 230 feet above the level of the canal in Syracuse, and it is to be of a capacity of seventy million gallons. The natural elevation of this distributing reservoir is sufficient to supply all except the highlands of the city with water by gravitation, sufficient for fire purposes, avoiding the necessity of using fire engines in all the business portions of the city; and will afford as great pressure as is economical or practicable. For supplying the higher parts of the city it is proposed to erect a stand pipe at the site of the reservoir, which will supply by gravity all those portions. It is proposed that the works thus to be constructed shall be of sufficient capacity to supply water to all parts of the city for all purposes for a period of fifteen years, and that to make the works capable of supplying the city with water for a period of fifty years it will only be necessary to lay an additional pipe or pipes

from Skaneateles Lake to the distributing reservoir. The pipe line from Skaneateles Lake to the distributing reservoir will be substantially on the hydraulic grade, and therefore the pressure and danger of accident will be reduced to a minimum.

It is proposed to connect the pipe from the distributing reservoir with the present pipe system of the Syracuse Water Company, and to use all that is available, making such additions and changes as may be necessary.

The plan includes the construction, should it be necessary, of a reservoir on Carpenter's Brook, covering 664 acres, and of a capacity of 6,037,000,000 gallons, from which to supply the Erie Canal with water, in exchange for the water to be taken from Skaneateles Lake. The site for this compensatory reservoir may be so located that its availability for the purposes of the canal cannot be questioned, and will supply the canal with more water than is taken for canal purposes from Skaneateles Lake.

The foregoing plan of construction is entirely practicable, and is of the simplest character from an engineering standpoint.

Cost of Construction.

Our conclusions in respect to the cost of construction of the works necessary for the distribution of water to all parts of the city from any source, must be based almost entirely upon the estimates made by Mr. Croes, under whose direction the necessary examinations have been made. From the data thus furnished to us, a detailed statement of which is contained in his report, we conclude as follows:

1. Works necessary to supply all parts of the city with water from Skaneateles Lake by gravity, it is estimated will cost about the following sums: Gate-house and inlet at the lake; conduit line of 30-inch cast iron pipe to distributing reservoir on Knapp's Hill; reservoir capable of containing 70 million gallons of water; high service stand-pipe 100 feet high at reservoir, and water damages on Skaneateles Creek, $1,379,141. In this estimate we believe that we have allowed more than is necessary for compensation to the property owners on Skaneateles Creek. In case it should be found necessary to construct a reservoir at Carpenter's Brook for the purpose of supplying the Erie Canal with water in

exchange for that taken from Skaneateles Lake, we estimate that the cost of such reservoir will not exceed $750,000. If to these sums should be added the cost of securing the property and plant of the Syracuse Water Company, the total expenditure required for bringing water from Skaneateles Lake and distributing it to all parts of the city by gravity would not exceed the sum of three millions of dollars.

2. Works necessary to supply all parts of the city with water from Salmon River, including the amount to be paid to the Syracuse Water Company, damages to property owners on Salmon River, the proposed dam, and all other incidental expenses, will cost four millions of dollars.

3. Works necessary to supply all parts of the city with water from Onondaga Creek at Cardiff and the Tully Lakes, including a sum which at five per cent. would yield $60,000 per annum, that being the cost per annum of pumping the necessary amount of water into a distributing reservoir, and including the sum necessary to acquire the plant and property of the Syracuse Water Company, damages to property and other incidental expenses, will cost three millions of dollars.

4. Works to supply all parts of the city with water from Oneida Lake at Shackleton's Point, including a sum which, at five per cent., would yield $75,000 per annum, that being the annual cost of pumping the necessary amount of water into a distributing reservoir, and including the necessary sum to acquire the plant and property of the Syracuse Water Company, and all incidental expenses, will cost three million four hundred thousand dollars.

The foregoing are estimates of cost of works of sufficient capacity to supply all parts of the City of Syracuse with water for a period of fifteen years.

It will be seen that the cost of construction of the necessary works for procuring water from Skaneateles Lake will be less than from any other available sources when the annual cost of pumping the necessary amount of water into a distributing reservoir from a source from which it cannot be supplied by gravitaiton, is taken into consideration.

Rights of the State in the Waters of Skaneateles Lake.

It has been suggested that by Section 6 of Article 7 of the Constitution of the State it would be impossible for the City of Syracuse to obtain Skaneateles Lake as a source of water supply, for the reason that it constitutes a part of the Erie Canal, and is therefore the property of the State and cannot be disposed of by it. The section is as follows: "The Legislature shall not sell, lease or otherwise dispose of the Erie Canal, the Oswego Canal, the Champlain Canal, the Cayuga and Seneca Canal, or the Black River Canal, but they shall remain the property of the State and under its management forever." The Constitution does not define what the Erie Canal consists of, but by Article 1, Title 9, Chapter 9, Part 1, of Revised Statutes, the Legislature has enacted as follows:

"Section 1. The navigable connections heretofore constructed and now in the process of construction by the State" (which includes the Erie Canal) "shall be known and designated as follows:

"1. The navigable connections connecting the waters of Lake Erie with those of the Hudson River, and of the side-cuts, feeders and other works belonging to the State, connected therewith, by the name of the Erie Canal."

The first suggestion which occurs to us is that if it is competent for the Legislature of the State of New York to enact that all feeders of the Erie Canal shall become and be a part thereof, it is equally competent to declare that certain feeders shall cease to be a part of the canal, especially when such feeders cease to be necessary or useful for this purpose.

The Constitution does not make Skaneateles Lake a part of the Erie Canal. What the Constitution means is, that the Erie Canal, the channel across the State and the waters necessary for its use, shall not be sold, and not that any feeders originally designated by the State as forming a part of it may not be disposed of, and others substituted in their place.

This view is strengthened by a consideration of the changes made in the Constitution of 1822, by the later constitutions of this State. The Constitution of 1822 provides as follows:

CONSTITUTION OF 1822, ARTICLE 7, SECTION 10.

"Rights of toll * * shall be imposed on and collected from all parts of the navigable connections between the great Western and Northern lakes and the Atlantic Ocean, which now are or hereafter shall be made and completed * * . And the Legislature shall never sell or dispose of said navigable connections or any part or section thereof; and the same shall be and remain the property of this State."

The language of the Constitution of 1846, and the present Constitution, both provide that the Erie Canal as a whole shall not be disposed of; this change of phraseology would seem to indicate an intention that such portions thereof as should no longer be necessary for its proper use might be devoted to other purposes.

By Section 75, Article 4, Title 9, Chapter 9 of the first part of the Revised Statutes, the Legislature has enacted that whenever any water may be spared from any canal or works connected therewith without injury to the navigation or safety of such canal, a sale of such surplus water may be made. It is true that the act provides that the State shall have the right wholly to resume the water so conveyed and the privileges thereby granted whenever it shall become necessary for the use or safety of the canal. We quote the above for the purpose of suggesting that if the State, by act of the Legislature, has the power to make a revocable grant of waters of a feeder of the canal, but not necessary for its use and safety, it has the power to enact that an irrevocable grant of such waters may be made. By the proposed plan of construction it is designed, if it should become necessary, to supply to the canal from other sources, as much water as will be taken from Skaneateles Lake for the purposes of the city. Such exchange of water could in no way impair the usefulness or safety of the Erie Canal, or in any manner injure the interests of the State. It seems to us, also, that a forced or technical interpretation of the

Constitution would not be resorted to, which would preclude the possibility to a municipality of nearly 100,000 people of securing a proper and suitable source of water supply. We believe that the necessities of our city in this regard are so urgent, its welfare and prosperity so largely dependent upon securing water from this source, that the authorities of the State would feel constrained to accede to the demand of the city for this water as a source of supply.

Availability and Present Value of the Works of the Syracuse Water Company.

We have inquired into the availability of the present water-works of the city as a part of the proposed system, and we believe they may be made available for a portion of the city, by using the reservoirs and the main pipes or some portion thereof for a part of the distribution system. As to the present value of these works, the act creating this Board has not conferred those powere that are essential to enable us to prosecute such inquiry to any satisfactory or just conclusion. With our limited information on this important subject we deem it our duty to omit any attempt at estimating the present value of these works. In our opinion, if the city should determine to acquire the works and plant of the Syracuse Water Company, a careful and thorough investigation should be made as to the value thereof, and a fair and just compensation paid to the owners.

City Ownership.

In our opinion it is greatly to the interest of the people that the works supplying water should be owned and controlled by the city. It is shown by statistics that when private corporations control city water-works, the cost to the individual using the water is greater, and the works are less comprehensive and efficient than when the public control the works.

For a clear and detailed statement and discussion of this subject we here refer to pages ~~61-64~~ 50-53 inclusive, of Mr. Croes's report, and to diagrams appended thereto, designated as Plates 9 and 10.

It is believed that an expenditure of even $3,000,000 by the city for the construction of works to supply water from Skaneateles Lake, would be wise and economical; and would secure to the city an abundant supply of wholesome water without increasing the burden of the taxpayers.

In our opinion the necessary sum can be borrowed on the bonds of the city, having fifty years to run, at so low a rate of interest that a sufficient revenue can be derived from the proposed water-works to provide for the interest account, the cost of maintenance, and an adequate sinking fund; and the cost of water to the city and to the individual would be less than under any system of private ownership.

CONCLUSIONS.

We unanimously recommend—

1. That the City of Syracuse secure Skaneateles Lake as a water supply.

2. That the City of Syracuse own its own water-works.

3. That the City secure the ownership of the works and plant of the Syracuse Water Company upon the basis of a fair compensation to the owners thereof.

4. That the Common Council take the requisite steps to secure the necessary legislation for procuring Skaneateles Lake as a source of water supply and the acquisition of the property of the Syracuse Water Company.

Respectfully submitted,

E. B. JUDSON,
JAMES B. BROOKS,
ALEX. H. DAVIS,
P. B. MCLENNAN,
W. H. WARNER,
W. K. NIVER,
Commissioners.

SYRACUSE, N. Y., February 1st, 1889.

EXHIBIT A.

Expenditures by the Board of Special Water Commissioners:

Salaries, Engineers and Clerk of the Board	$4,650.00
Pay rolls, engineers and assistants	1,694.03
Subsistence, " "	1,053.45
Transportation, " "	235.70
Livery Hire, " "	326.70
Traveling Expenses	240.46
Incidentals, Stationery, etc	212.50
Sinking Test Tubes	498.19
Analyses	723.30
Printing: Commissioners' and Engineers' reports, including maps and diagrams	1,278.00
Rent	222.22
Interest	14.06
	$11,147.61

Vouchers for the above on file at the office of the City Treasurer.

EXHIBIT "B."

List of Maps and Profiles accompanying the Report of the Special Water Commission :

1. Map of the line of Conduit from Skaneateles Lake to Syracuse. Scale, 1 inch=400 feet.

2. Map of the proposed Reservoir site, Cardiff Valley. Scale, 1 inch = 400 feet.

3. Map of the proposed site, Carpenter Brook Reservoir. Scale, 1 inch = 400 feet.

4. Map of the proposed reservoir site, Salmon River Valley. Scale, 1 inch = 400 feet.

5. Map of the conduit line crossing the summit between Salmon River and Fish Creek. Scale, 1 inch=800 feet.

6. Map of the water-shed of Carpenter Brook Reservoir. Scale, 1 inch=200 rods.

7. City map showing location of fire hydrants and location and size of water-mains. Scale, 1 inch=¼ mile.

8. City map showing heights at different points above canal level. Scale, 1 inch=¼ mile.

9. Profile of conduit line from Salmon River to Syracuse. Horizontal scale, 1 inch=200 rods; vertical scale, 1 inch=60 feet.

10. Profile of conduit line from Oneida Lake to Syracuse. Horizontal scale, 1 inch=200 rods; vertical scale, 1 inch=60 feet.

11. Profile of conduit line from Skaneateles Lake to Syracuse. Horizontal scale, 1 inch=200 rods; vertical scale, 1 inch=6 feet.

12. Profile from Tully Lakes and Cardiff Reservoir site to Syracuse. Horizontal scale, 1 inch=200 rods; vertical scale, 1 inch=60 feet.

LIST OF ENGINEER'S NOTE-BOOKS ACCOMPANYING THE REPORT OF THE SPECIAL WATER COMMISSION.

Transit Books.

Contents.

No. 1. Salmon River, Skaneateles Lake, Carpenter Brook.

No. 2. Salmon River, Skaneateles Lake, Cardiff, Gang Wells, University Hill Reservoir.

3. Salmon River, Skaneateles Lake, Gang Wells, Carpenter Brook.

No. 4. Cardiff, Carpenter Brook.

No. 5. Carpenter Brook.

No. 6. Oneida Lake.

No. 7. Cardiff Reservoir.

Level Books.

Contents.

No. 1. Salmon River, Onondaga Creek, University Hill, St. Cecelia Cemetery Hill, Gang Wells.

No. 2. Salmon River, Skaneateles Lake, Gang Wells.

No. 3. Skaneateles Lake, Gang Wells, Carpenter Brook.

No. 4. Cardiff Reservoir.

No. 5. Carpenter Brook, Tully Lakes, Levels in City, Otisco Lake.

No. 6. Oneida Lake.

ENGRAVED MAPS AND DIAGRAMS ACCOMPANYING ENGINEER'S REPORT.

Plate 1. General Map of Sources of Supply.
Plate 2. Cross-section of Salmon River Valley.
Plate 3. Profile, Salmon River to Syracuse.
Plate 4. Water-shed of Skaneateles and Otisco Lakes.
Plate 5. Profile, Skaneateles Lake to Syracuse.
Plate 6. Cross-section of Valley at Cardiff.
Plate 7. Profile, Tully Lakes and Cardiff to Syracuse.
Plate 8. Section at Gang Wells.
Plate 9. Water-rates; Works owned by Towns.
Plate 10. Water-rates; Works owned by Companies.
Plate 11. Distributing System of Syracuse Water Company.

CHAPTER 532.—N. Y. STATE LAWS OF 1888.

AN ACT to authorize the City of Syracuse to provide for an investigation of the sources of water supply for said city for public, mechanical and domestic uses.

APPROVED by the Governor June 9, 1888. Passed, three-fifths being present.

The People of the State of New York, represented in Senate and Assembly, do enact as follows:

SECTION 1. The mayor of the City of Syracuse, by and with the advice and consent of the common council thereof, is hereby authorized to appoint six citizens of said city, three from each of the two principal political parties into which the citizens thereof are divided, who shall constitute a board of special commissioners to inquire into and investigate the sources of water supply for said city for public, mechanical and domestic uses. Said commissioners shall serve without compensation, but the necessary expenses incurred by them while in the discharge of their duties shall be allowed and paid to them by the city treasurer of said city upon vouchers therefor to be approved by the mayor. In case any vacancy occurs in said board by the death, resignation or removal from the city of any of such special commissioners, the mayor shall forthwith fill the same by the appointment, in like manner, of a citizen of said city of the same political faith as the retired special commissioner. A majority of said board shall

constitute a quorum, and the assent of a majority of the board shall be required to validate any transaction of business on the part of the board.

SEC. 2. Within fifteen days after the passage of this act, and on a day to be designated in writing to them by the mayor of said city, the said special commissioners shall meet, at twelve o'clock, noon, at the mayor's office in the city hall of said city; and after having each taken, subscribed and filed in the office of the city clerk of said city the constitutional oath of office, shall elect one of their number as chairman of the board to preside over their deliberations, and another of their number as secretary of the board who shall keep a true record of their proceedings which shall, at all reasonable times, be subject to the inspection of the said mayor, the common council or any committe thereof appointed or designated for such purpose. Notice of such elections shall be transmitted by them to the mayor, the common council and the city treasurer. The said special commissioners shall designate a day and hour and a place for their regular meetings which shall be entered of record, and which may be changed by them from time to time; they may adjourn from day to day, and may meet upon the call of the chairman of the board, upon written or printed notice thereof signed by him, and given either personally or through the post-office, postpaid, addressed to each of the other special commissioners at his place of residence or business, at least one day before the time for such meeting. The common council of said city shall assign to said board some suitable room for the meetings of the board.

SEC. 3. The said special commissioners are hereby authorized to employ a civil engineer who is skilled in hydraulics and competent to advise said board as to the characteristics of the several waters they may examine, and such other experts and assistants as they may deem necessary for the prosecution of their investigation, and to fix the rate of their compensation which shall be paid to them monthly, upon the certificate of said board and upon vouchers to be approved by the mayor; but the total amount of their expenditures or liabilities for compensation of employees and all expenses attending the investigation shall not exceed the

sum of twelve thousand dollars; which amount the said common council is hereby authorized to appropriate for such purpose, and, in addition to the amount now required to be raised by tax for said city, to cause the same to be raised by a tax upon the taxable property in said city, in the same manner as the other general taxes are levied and collected.

SEC. 4. It shall be the duty of said special commissioners, immediately after their organization and the employment of competent assistants, to proceed to inquire into, and to investigate the several sources of a water supply which may be made available for the public, mechanical and domestic, uses of said city. Such investigation shall have regard to the abundance of the supply of water, and its quality and character; and in case they shall determine to recommend, for adoption by the city, any source of supply which they shall have investigated, or any system or plan for the distribution of water throughout the city, they shall prepare a detailed plan for the construction of works therefor, including the location of reservoirs, and shall make and report to the common council an estimate of the cost of such construction, showing distances of transportation and whether the water will be supplied to all parts of the city by gravitation or otherwise. They shall also inquire into the availability of the present water-works in said city as a part of such system which they may recommend, and an estimate of the present value thereof, and shall include the same in their report, which shall be transmitted to the common council, together with their recommendations on or before the tenth day of January, eighteen hundred and eighty-nine, when all books and papers relating to such investigation, and all property belonging to said city, in the possession or under the control of said special commissioners shall be deposited by them in the office of the city clerk of said city, to be disposed of as the common council may direct; and thereupon the powers and duties of said special commissioners shall cease and determine.

SEC. 5. This act shall take effect immediately.

By an act passed January 10, 1889, the time for making the report was extended until February 1, 1889.

II.—REPORT OF ENGINEER.

REPORT
ON SOURCES OF WATER SUPPLY FOR SYRACUSE, N. Y.

By J. J. R. CROES, C. E.

NEW YORK, January 28th, 1889.

To the Honorable

E. B. JUDSON, President; J. B. BROOKS, A. H. DAVIS, P. B. MCLENAN, W. K. NIVER, and W. H. WARNER, Special Commissioners to inquire into and investigate the sources of water supply for the City of Syracuse.

GENTLEMEN: I have the honor to present the result of the examinations made under your direction, in pursuance of Chapter 532 of the New York State Laws of 1888, to investigate the several sources of a water supply which may be made available for the public, mechanical and domestic uses of the City of Syracuse.

In accordance with your resolution of July 17th, 1888, the investigations have included the character and quantity of water which can be procured, and the cost of construction of the necessary works for bringing water from the following sources, which comprise, it is believed, all that can in any way be considered practicable.

1.—The Salmon River.
2.—Skaneateles Lake.
3.—Lake Ontario.
4.—Seneca River, including Cayuga and Crooked Lakes.
5.—Onondaga Creek at Cardiff.
6.—Ground water in the valley of Onondaga Creek, procured by driven wells.
7.—Cazenovia Lake.
8.—Oneida Lake.
9.—Otisco Lake.
10.—The Tully Lakes.
11.—The existing works of the Syracuse Water Company, comprising springs and the water of Onondaga Creek near the City.

With your concurrence, I secured the services of Mr. W. R. Hill, C. E., to make the requisite surveys and specific examinations, a duty which he has performed in a most thorough and efficient manner.

In obtaining information as to the various projects for supply, we have been aided by the data furnished by the Syracuse Water Company, the Central City Water Company, and Mr. W. A. Sweet the projector of the Salmon River supply, and by the report made in 1887 by Mr. James T. Gardiner, C. E., to the State Board of Health on the sanitary qualities of proposed water supply for Syracuse.

The preliminary investigations of these observers have so far determined several of the most available points from which a supply can be drawn and the routes by which water can be brought to the City, that much time has been saved in the surveys and examinations, by using so much of the information furnished as was easily verified.

QUANTITY OF WATER.

Any source of supply should be capable of furnishing water enough to supply Syracuse for at least fifty years, and the works first constructed should be of capacity to deliver a sufficient supply for fifteen years, the period in which the cost, reckoned at 4¾ per cent. compound interest, will double itself.

The population of Syracuse is now about 90,000. The increase of the population in cities of this size varies from 4,000 a year as in Buffalo, to 7,000 a year, as in Cleveland and Pittsburgh. Judging from the number of votes cast at Presidential elections the average growth of Syracuse between 1880 and 1884 was 2,600 per annum, and between 1884 and 1888 was about 4,100 per annum. For the next ten years it may be safely estimated at 5,500 per annum, and for the following ten years at 7,000, and after that at 8,000 per annum.

The supply of water needed cannot safely be reckoned at less than 80 gallons daily per head.

The source of supply therefore should be capable of furnishing at least 37 million gallons a day, and the works to be first built should have a capacity of 15 million gallons per day.

The amount of water which can be depended upon in this latitude and vicinity, from a stream or lake, is about 600,000 gallons per day per square mile of water-shed, provided that storage for at least 120 days' supply can be obtained. Any source of supply should therefore possess at least 60 square miles of tributary water-shed, and capacity for storage of at least 4,500 millions of gallons.

The first storage reservoirs built, must have a capacity of about 1,800 million gallons.

THE SOURCES OF SUPPLY.

(1.) The Salmon River water-shed, above the best point of diversion of the water, comprises 70 square miles of forest land from 1,000 to 1,500 feet above the level of the sea, about 40 miles northeast of Syracuse. The brooks tributary to the main stream head in springs, and for the first few miles of their course flow through swamps. Along the main stream the fall is rapid, and there is very little vegetation on the beds or shores, which are of sandstone and gravel. The water is generally clear but of a brownish tint. The timber available for lumbering and for bark has been mostly cut out; and most of the land formerly cultivated has been allowed to grow up again with timber. Mr. Gardiner estimates that from 80 to 85 per cent. of the water-shed is wooded. The village of Osceola, of some 40 houses, is the only settlement in the water-shed. There are a few other detached dwellings.

A favorable location for a storage reservoir exists about three miles above Redfield, on the east branch, where a dam 32 feet high will impound 1,816 million gallons at an elevation of 590 feet above Syracuse. Between this point and the mouth of the Salmon River, at Lake Ontario, there are a number of water-powers, some of which are unoccupied, but there are in operation on the stream, 24 mills the machinery of which is driven by water-power, the aggregate capacity of the wheels being 1,235 horse-power.

At the site selected for the storage reservoir, there is a high ridge on the south of the valley, which makes it impracticable to carry a pipe by the most direct line to Syracuse. This ridge falls off about two miles down stream from the dam site, and at that point it is practicable to cross the divide to the head-waters of

Fish Creek with only moderate cutting. After passing eight miles along the slopes of the hill sides, the ground falls off rapidly, so that at ten miles from the dam the conduit line will be under about 400 feet head. In the next 15 miles the surface falls to 600 feet below the reservoir and continues at this level for 15 miles more to the city line.

The total distance from the storage reservoir to the distributing reservoir proposed to be built on University Hill, at an elevation of 250 feet above the canal, is 42.72 miles. To avoid the danger and expense of having 15 miles of pipe line under a constant head of 600 feet, the conduit may be divided into two sections by a small reservoir at Spicer's, 14 miles from the storage reservoir, fed from the storage reservoir by a 28-inch cast-iron pipe, capable of discharging 15,000,000 gallons per day when the storage reservoir is drawn down 25 feet. The flow line of this small reservoir to be 317 feet above the canal at Syracuse, and from it a 42-inch cast-iron pipe to lead to a reservoir on University Hill, 250 feet above the canal. The capacity of this pipe will be 15,000,000 gallons a day, and the head on it across the 15-mile flat will not exceed 140 pounds to the square inch.

(2.) Skaneateles Lake is situated in the southwesterly part of Onondaga County, 16 miles in a straight line from Syracuse. The lake is 15 miles long and generally 1 mile wide with an area of 12¾ square miles. Its axis and flow are in a northwesterly direction. The western water-shed has an area of 27¼ square miles, with a maximum width of 2¼ miles and a minimum width of ⅓ of a mile. The eastern water-shed has an area of 30¼ square miles, with a general width of 1½ miles.

The total area of water-shed, including the lake, is 70.25 square miles.

Borodino, a village of 50 dwellings, is situated on the eastern shed, 7 miles from Skaneateles, and ½ mile from the lake.

Spafford, a village of 30 dwellings, is situated on the eastern shed, 12 miles from Skaneateles, and 1 mile from the lake.

Scott, a village of 20 dwellings, is situated 1½ mile southerly from the lake.

Fair Haven, a village of 15 dwellings, is situated on the eastern shore at the head of the lake.

Mandana, a village of 12 dwellings, is situated on the shore of the lake, 5 miles from Skaneateles.

New Hope, a village of 40 dwellings, is situated 12 miles from Skaneateles on Bear Swamp Creek, and 2 miles from the lake.

Glen Haven, a summer resort, comprising a hotel and water cure, and about 10 cottages, is situated on the west shore at the head of the lake.

On the entire water-shed, including the above-mentioned villages, there are 600 dwellings.

The water-shed is high rolling ground, partly under cultivation, but covered to a great extent with timber.

The lake is very deep, and the shores are bold and free from vegetable growth at the water's edge.

The right to use a certain proportion of the flow from this lake is controlled by the State of New York for the purpose of supplying the Jordan Level of the Erie Canal with water. In 1844 the State constructed a sluice-way to enable the surface of the lake to be drawn down 5 feet, and thus supply an amount of water which was estimated at 7,520 cubic feet per minute for 100 days. The outlet has since been deepened to 9 feet below high-water level, and the available supply for the Canal is reported as 8,776 cubic feet per minute for the period of navigation, which varies from 197 to 269 days during a year, averaging 225 days.

During the period when the canal is closed for navigation, the mills on the course of the stream between the lake and the canal have to be supplied with water for power. There are on this stream 25 dams, furnishing head for driving 68 turbine-wheels, with an aggregate of about 3,000 horse-power. To supply these mills it is necessary to permit about 4,000 cubic feet per minute, or about 43 million gallons a day to waste from the reservoir while it is filling up during the winter season. In fact there is permitted to run to waste about 60 million gallons a day during this time, or about 8,400 millon gallons during the 140 days that the canal

does not need the water. This alone would suffice to supply Syracuse with over 23 million gallons a day for the whole year, if it could be stored for use.

This water does not belong to the State, as I understand the case, but is the property of the mills, and it would probably be possible for the city to condemn the mill privileges and acquire the right to the water for the period that the canals are closed to navigation. It would not be easy to store all the surplus water thus acquired, so as to utilize it during the 225 days that the canals are in operation. If, however, a sufficient quantity of water from this source or any other, can be stored or delivered at the expense of the city anywhere where it may be used to supply the Jordan Level during the period of navigation with an amount of water equal to that needed for the city from Skaneateles Lake, it does not appear to me to be likely that the State could object with reason to such an exchange of waters.

I find that it would be entirely practicable to make such an exchange by either one of two methods.

A good site exists on Carpenter's Brook, between Lake Skaneateles and Syracuse, for constructing a storage reservoir holding 6,037 million gallons, equivalent to a daily supply of 27 million gallons for 225 days. This brook is one of the feeders to the Jordan Level and its regular flow is estimated at 200 cubic feet per minute or about two million gallons a day. The water-shed above the proposed reservoir site is 14⅔ square miles. The entire flow of the stream in a dry year would not fill this proposed reservoir, but enough of the surplus of Skaneateles Lake could be diverted into it to ensure its filling during the dryest year and thus furnishing the canal with the entire available flow from its water-shed and from Lake Skaneateles, instead of only the summer flow from both of them and part of the winter flow of Skaneateles as at present.

The other method would be by pumping from the Seneca River into the Jordan Level, an amount of water equal to that taken by the city from Skaneateles Lake.

This method does not appear to me to be desirable. It would not .relieve the city of the expense of extinguishing the water

rights on Skaneateles Creek. It would involve the expense of maintaining an expensive steam-pumping station for two-thirds of the year in an isolated location so far from the city that proper supervision would be difficult, and also with the care of the station with the costly machinery lying idle for the remaining third of the year. Whether this work should properly be done by the city, or be done by the State, and paid for by the city, either as an annual fixed charge or by payment of a gross sum, are questions which cannot even be discussed at this time with any probability of reaching conclusions of any value.

The plan proposed for bringing water from Skaneateles Lake is to lay a cast-iron pipe of 30 inches diameter from a point about 1,000 feet out in the lake to a distributing reservoir on Knapp's Hill, on the western boundary of the city, at an elevation of 230 feet above the canal. At this point a stand-pipe 100 feet high, to be also erected, from which a special main would be laid to supply the high ground in the southeasterly part of the city.

(3) Lake Ontario is about forty miles north of Syracuse. The low-water elevation of the lake surface is 158.62 feet below the canal at Syracuse. The water would have to be pumped through 40 miles of pipe and to an elevation of at least 400 feet. The frictional head in a 36-inch pipe of this length, delivering 15 million gallons a day, would be about 280 feet, so that the practical pumping lift would be 680 feet, equivalent to a pressure of 300 pounds per square inch on the pumps. The annual cost of pumping by water power would be at the very least estimate, $75,000, or by steam power, $300,000, which would be the interest on $1,500,000 and $6,000,000 respectively. The cost of pumping works and pipes would be not less than $2,500,000, so that a supply from this source would represent an expenditure of from 4 to 8 million dollars, even if the water were fit to use.

I do not find that any town on the south side of Lake Ontario takes its water supply from the lake. On the Canada side, Toronto, Kingston and Parkdale use lake water, but it is not altogether satisfactory. As is shown later on in this report, the analysis of samples of the water procured from outside the breakwater, two miles from Oswego, with the wind blowing from

the north and the current setting in from the deep water of the open lake, showed the character of the water to be objectionable for domestic supply.

(4.) The Seneca River was examined between Baldwinsville and Cayuga Lake. The water-shed is sufficient to furnish the required quantity of water, but the stream is sluggish for long distances, passing through extensive marshes, and the population on the drainage area is too dense to permit any hope of procuring good water from the river, even if favorable conditions existed for constructing storage reservoirs to enable the supply to be kept up during the dry months.

(5.) Onondaga Creek at Cardiff. About ten miles south of Syracuse, near the south end of the Indian Reservation, the valley of Onondaga Creek narrows to a gorge, with high, steep banks, and then widens again, affording a favorable location for the construction of an impounding reservoir. The apparent water-shed tributary to the stream at this point has an area of 40 square miles, partly cultivated and partly in forest. The population is small. The rock is largely shale. The gravel overlying the rock is deep and apparently very pervious to water, particularly at the southern end of the main valley, where a number of very copious springs feed the brooks. It is probable that a not inconsiderable amount of water is thus contributed from the plateau south of the natural southern divide of this valley, in which are situated the Tully Lakes, which have no surface outlet. It is therefore very probable that with proper storage facilities an average daily supply of oyer 30 million gallons could be derived from this source. The apparent drainage area can certainly supply, at the least calculation, 25 million gallons a day.

The level of the stream at the proposed dam site at Cardiff is 72 feet above the Erie Canal at Syracuse. A series of test borings was made across the valley at this point, showing the existence of a good foundation of shale rock not very far below the surface on the westerly bank, and continuing on a slope eastwardly under the hill on the east side of the stream.

A dam 52 feet high and 600 feet long on top can be built here and make a fine storage reservoir 3½ miles long and

covering 813 acres and holding 4,340 million gallons. The water surface being only 120 feet above the canal and 9.6 miles distant from the centre of the city, sufficient head cannot be obtained by gravity, and it is, therefore, proposed to convey the water by a 36-inch pipe, 8.27 miles, to a convenient point on the line of the Syracuse, Binghamton and New York Railroad, and thence pump it 1.33 miles to a reservoir on University Hill, 250 feet above the canal, and a tank stand-pipe 100 feet higher for high service supply.

In case of an increase of supply being needed it will be practicable to connect and drain into this valley the water-shed of the Tully Lakes which lie to the south. This water-shed, of 13.72 square miles, was examined by me in 1871, and I quote from my report then made to the Joint Committee of Aldermen and Citizens, the following description of it:

"The Tully valley is situated about twenty miles south of Syracuse. At the head of the valley of Onondaga Creek, a natural dyke crosses the valley, and forms the divide between the waters flowing to the north and to the south. On the south side of this ridge, which is about a mile in width, lies what is called the "Tully Flats," a tract of land about two miles wide, nearly level from east to west, and sloping to the south at the rate of 13 feet to the mile. On each side it is bounded by steep and high hills, the summits of which are about four miles apart.

"On the westerly side of this valley are several depressions in the surface, varying in size from half an acre to about 230 acres. Where the bottoms of these depressions are below a certain plane, they hold water for the whole year; when above that plane water stands in them at certain seasons, but for a great portion of the year they are dry. This plane, or rather pair of planes, may be described as rising on each side of a north and south horizontal line through the main depression, at the rate of 29 feet to the mile. The four larger depressions, which are called the Tully Lakes, and the bottoms of which are from 30 to 80 feet below the plane spoken of, lie within a space 10,000 feet long and 8,000 feet wide. Their areas and depths, at their ordinary water levels, are as follows:

Name.	Area in Acres.	Elevation above Canal at Syracuse.	Extreme depth.	Location
Big Lake.....	231.7	787	33	S. end of main depression
Green Lake.....	39.9	788	65	N. " " "
Van Hoesen Lake.....	120.2	793	35	1,000 feet west of Big Lake
Crooked Lake..... ..	144.9	794	80	4,000 " " Green "

"Green Lake was originally a portion of Big Lake, but the channel connecting them is now silted up, leaving only a small passage for the water which now flows into Big Lake and thence into Tioughneoga Creek. No stream flows into Green Lake. It receives most of its supply of water from the gravelly plain extending about a mile to the east of it, nearly level, and forty feet higher than its surface.

"A brook, rising three and a quarter miles north of Tully village, passes one mile east of Green Lake, and empties into Big Lake, near its southern extremity. This brook is dry in the Summer, the water from the hills passing under its bed, and into the lakes to the west of it. The shores of Green and Big Lakes are underlaid with a white limestone, at a depth of eight feet below the water surface.

"The banks of Crooked and Van Hoesen Lakes are of gravel. Van Hoesen Lake has no visible inlet nor outlet. Crooked Lake is fed by two brooks which are dry in the Summer, the water sinking into the gravel and reaching the lake below the ground level. It has no natural outlet, but its waters have been for thirty-five years conducted to the north by an artificial channel. It is raised and lowered five feet by this draught.

"The purity of the water of these two lakes is explained by the fact that the hill to the west of them is composed almost entirely of shale, and the shores are of gravel with no limestone visible, while a portion of the water of Big and Green Lakes passes over a limestone region to the eastward before reaching the gravel.

"To obtain an approximate idea of the quantity of the water which these lakes can supply, a survey was made of the area of country drained by them. The topography of the region would

show this area to be 13.72 square miles (8,783 acres). The watershed of Van Hoesen Lake is 1.22 square mile, that of Crooked Lake 2.25 square miles, and that of Green and Big Lakes combined 10.25 square miles. To determine the exact proportion of this area which is tributary to Green Lake, is somewhat difficult. The area of that part which cannot possibly contribute to Green Lake is five square miles. Of the remainder, only one square mile is clearly tributary to Green Lake alone, leaving 4¼ square miles from which the water in heavy rains reaches Big Lake, while a portion of the flow from moderate rains, sinks into the gravel and reaches Green Lake."

(6.) Ground-water in the valley of Onondaga Creek procured by tube wells.

Three and a half miles south of Syracuse, the valley of Onondaga Creek is about half a mile wide at the level of the stream, and about 17 feet above the canal level at Syracuse, with a slope of about 6 feet per mile to the north, toward the city.

In the autumn of 1887, the Syracuse Water Company selected this plateau for an experimental test of the feasibility of procuring a supply of under-ground water. Eight pipes were sunk through the surface strata to a stratum of gravel which was found to be saturated with water. A steam-pump was attached and run for 82 days, pumping part of the time at the rate of 3,168,000 gallons per day, without apparently affecting the level of the ground water in the vicinity. The water was found, on analysis by Professors Chandler and Lattimore, to be very free from organic impurities, but very hard. According to Professor Chandler's analysis of February, 1888, the hardness (expressed in parts per 100,000) was 30.15, while that of the city supply in the reservoir was 37.62, according to Professor Lattimore's analysis of July 29, 1886, as given by Mr. Gardiner.

In September, 1888, a more elaborate test was made by the Water Company, by putting in a plant of 32 tube wells, 24 being of 6 inches diameter, and 8 of 4½ inches. The wells were 50 feet apart and were sunk 40 feet. The 6-inch wells were attached to two collecting mains of 600 feet in length

meeting at right angles, and at the point of junction two centrifugal pumps were placed, driven by steam. The 4½-inch wells were connected by a main 400 feet long, attached to another pump. A number of test tubes were sunk in the vicinity to observe the effect of the pumping on the level of the ground-water.

The location of the plant and the test tubes, and a section of the ground indicating the strata, and the elevation of the water at different times, are shown on the accompanying plan. (Plate 8.)

I had the subterranean strata examined by sinking test tubes and procuring samples of the material for each foot in depth. After passing through the top soil, there were found about 10 feet of loose gravel and clay, free from water, then 6 feet of hard-pan, impervious to water, and then about 22 feet of water-worn shaly gravel, saturated with water under a considerable head, the water rising in the tubes to 7 or 8 feet above the bottom of the hard-pan stratum. The thickness of the strata at three of the tubes is given in the following table:

	Tube No. 22.	Tube No. 24.	Tube No. 23.
Surface of ground, above canal at Syracuse	+13.7	+16.0	+20.5
Thickness of loose gravel and clay stratum	12.7	11.0	12.0
Elevation of top of hard-pan stratum	+ 1.0	+ 5.0	+ 8.5
Thickness of hard pan stratum	6.0	6.0	6.0
Elevation of top of sand and gravel	− 5.0	− 1.0	+ 2.5
Thickness of sand and gravel	About 22 feet		

The hard-pan stratum dips to the north 7 feet 3½ inches per mile. Assuming it to extend northward to the city with the same dip, the top of hard-pan would be 21 feet 10 inches below the surface of water in canal.

A profile of the bottom of Onondaga Creek from Tube 22 to Tube 23 shows the deepest pockets in creek to be above the hard-pan stratum.

Pumping was begun on September 4, the water in the ground standing in the test tubes at an elevation of 8.5 feet above the canal at Syracuse, and the surface sloping to the south at the rate of 3 feet to the mile. The pumps were run continuously until October 5 pumping, according to the estimates of the owner, 250

million gallons, or at the rate of 8 million gallons a day. The measurements of the flow of water made by my direction do not sustain this claim. I do not think that at any time the rate of pumping exceeded 7 million gallons a day and was generally not over 6 million gallons. At the end of this 31-day test, the surface of the under-ground water was bowl-shaped, being about 6 feet below the original surface at the centre of the wells, and 4 feet below at the circumference of a circle of 1,500 feet diameter. The pumps were stopped for 24 hours and the water rose in this bowl about three feet in the middle, 15 inches at the south or up-stream edge and 8 inches at the down-stream edge.

Pumping was resumed on October 6 and continued until November 4 with three stoppages aggregating 66 hours to one of the pumps, the other pumps being, however, run at increased speed during the stoppages. According to the estimate of the owners of the pumps, 220 million gallons were pumped during this 29 days, an average of 7½ million gallons per day. My observations do not sustain this estimate, as at no time could I find the pumping in progress at a rate exceeding 6 million gallons a day.

The effect of this pumping was to cause the surface of the ground-water to assume the shape of a bowl 6 feet deep at the centre, and the edge 4 feet below the original surface at half a mile south of the centre and 3 feet below at half a mile north of the centre. Sixty days pumping had, therefore, lowered the ground-water an average of about 4½ feet over the area of a circle a mile in diameter. From the slope of the under-ground water surface, the area affected by this pumping must have extended at least 4 miles up and down the valley.

After the pumping had stopped it took 45 days for the natural flow of the subterranean stream to fill up the basin created by the pumping, to the level at which it stood before the pumping began. This, too, was at the season when the ground was saturated by the heavy rains of September, October and November, and the flow of the underground water was above the average, as was shown by the fact that from December 14 to December 29 the water in the test tubes rose five feet above the level at which it stood when the pumping began in September.

Whence this water comes and whence it discharges, cannot be discovered without much more thorough examination than it is now possible to make. The indications are, however, that the water-shed is not very extensive; that the flow is very variable and is seriously affected by a dry season; and that when it exceeds the summer flow, the discharge of the main body of water is by springs about three miles north of the site of the wells. The existence of the rock barrier across the valley at Cardiff, which was developed by the borings I made, shows in my opinion that the source of supply is not very deep seated or extensive. That the main flow comes from the south is shown by the fact that the water surface is on a slope from south to north. At the beginning of the pumping this slope was 3 feet to the mile. Sixty days' pumping, taking out at the very largest estimate what we assume to be 30 days' supply for Syracuse (450 million gallons), so drained the gravel bed that the surface slope of the water for the mile in which the pumps are located was only 9 inches, and it took 45 days to restore the depleted subterranean reservoir, and reëstablish the normal slope of the water. These facts lead me to the opinion that, irrespective of the quality of the water, which will be mentioned hereafter, the capacity of supply of this underground stratum is entirely inadequate to the needs of Syracuse.

(7.) Cazenovia Lake is situated in the westerly part of Madison County, 17 miles southeast of Syracuse. It is 3½ miles long and ½ mile wide, with its axis and flow in a southerly direction. The area of the lake is 1.75 square mile, and the water-shed, including the lake, 9 square miles.

The area is inadequate for the supply of Syracuse, and, moreover, the lake is controlled by the State as a feeder to the Rome Level of the Erie Canal.

(8.) Oneida Lake is about 15 miles northeast of Syracuse. Its axis and flow are in a northwesterly direction. It is about 20 miles in length, with a general width of 4¼ miles.

Its outlet is at Brewerton, 13 miles northward from Syracuse. The deepest water in the lake is said to be about 60 feet, but it is generally much shallower, having a mean depth of probably not over 20 feet. Its rise and fall is about ten feet, which leaves a

large area of the shore exposed when the water is low, as the beach is quite flat. The surface of the lake at ordinary high water is 30 feet below the surface of water in the Syracuse Level of the Erie Canal.

As the country surrounding the lake for a distance of about 12 miles is quite flat, the streams flowing into the lake have very little fall, and many of them pass through swampy land, with sluggish flow, and the water is thereby discolored and unattractive in appearance. Fishermen, who are familiar with the lake, state that the water swarms with water insects, and is frequently in the condition which is styled "broomy" or full of a filamentous vegetable growth.

The area of the water-shed of the lake is 1,327 square miles, and includes part of the city of Rome. On this water-shed there are 18,000 dwellings, which at a moderate estimate would make the population 100,000.

Shackleton's Point is about the middle of the southern shore of the lake, and 16 miles northeasterly from Syracuse. It is located on higher ground than the surrounding country. One thousand feet from the beach the elevation of the ground is 30 feet above the surface of lake, and the same elevation as the surface of water in the Syracuse Level of the Erie Canal.

A conduit line from Shackleton's Point could be laid in the highway the entire distance, 16 miles, to a distributing reservoir on University Hill 250 feet above the canal. Including the friction in a 36-inch pipe, discharging 15 million gallons a day, the pumping lift would be about 400 feet, giving a pressure of 170 pounds per square inch on the pumps. A sufficient quantity of water can be procured from this source.

(9.) Otisco Lake is situated in the southwesterly part of Onondaga County, 2½ miles east of and parallel to Skaneateles Lake.

Its outlet is 12 miles in a straight line from Syracuse.

The lake is 5¾ miles long, and generally half a mile wide, with an area of 3 square miles. Its axis and flow is in a northwesterly direction.

The total area of water-shed, including the lake, is 41½ square miles.

Amber, a village of 12 dwellings, is situated on the eastern shore of the lake 1½ miles from its outlet.

On the entire water-shed, including the above-mentioned village, there are 430 dwellings.

At the foot of the lake the State has a dam with six (6) gates, 3 feet by 2 feet each. The high water of lake is 10.7 feet above the mudsill of dam. The present surface of the lake is 7 feet above mudsill.

"Nine Mile Creek," the outlet to Otisco Lake, flows in a northeasterly direction for 15 miles, and empties into Onondaga Lake, 4 miles northwesterly from Syracuse.

On this creek there are 20 dams and 30 mills, using 49 wheels, with an aggregate of 1,326 horse-power.

Half way between Camillus and Marcellus stations the State has a dam, from which runs a lateral canal 1¾ miles long, connecting with the Erie Canal.

In consideration for privilege of taking water from creek at Camillus, the State has agreed to keep in repair and in navigable condition the lateral canal from Patterson and Sisson's Flour Mill to the Erie Canal, a distance of one mile.

The N. Y. C. R. R. has a watering station which is supplied by this creek, and used only during the winter.

The capacity of the water-shed for city supply is about 25,000,000 gallons a day, with a storage of 3,000,000,000 gallons.

In 1843, the State made this lake a storage reservoir to supply water for the Erie Canal.

The capacity of the lake as a reservoir is rated as 5,146 cubic feet per minute, or about 55,500,000 gallons a day, for 120 days. To fill the lake to the height of the present dam it has several times been necessary to shut off the flow of the outlet for four or five weeks at a time during the winter, thus stopping the supply to the mills, and for these stoppages the State has to compensate the mill owners.

The lake being thus utilized by the State to its utmost capacity, a supply for the city could not be taken from it without impairing the water supply of the canal. The extinguishment of the water power rights on the line of the stream and the raising

of the dam at the lake might enable some water to be supplied, but not enough for the use of the city. The entire flow from Otisco Lake may, in a dry year, be as small as 9,000,000,000 gallons. The canal requires 6,600,000,000 gallons, leaving for other purposes 2,340,000,000, or an average of about 6,500,000 gallons a day.

Even therefore if the water were entirely satisfactory in quality, the supply is not sufficient for the city, nor can compensation water be furnished to the State from this lake, if Skaneateles Lake should be adopted as the source of the city supply.

(10.) The Tully Lakes have been already described. The water-shed is too small to supply the quantity needed, and the water from this source could only be used as supplemental to the Cardiff Dam project, adding about 8 million gallons a day to the supply.

(11.) The existing works of the Syracuse Water Company comprise a pumping station, 3 reservoirs, 37.11 miles of distributing mains, and 387 fire hydrants.

The present company was organized April 5, 1849, and succeeded to the rights and franchises held by Oliver Teall, who since 1829 had furnished water to Syracuse under authority from the Village Trustees, who by a law passed March 21, 1821, were empowered to take water from any springs on the State lands east of the village. The water was collected from Raynor and Stolfs springs and stored in a reservoir 107 feet above the canal. In 1870 the present distributing reservoir was built and in 1871 the company began pumping from Onondaga Creek, the gravity supply having proved insufficient.

The pumping station is located in the southern part of the city, on Onondaga Creek, and comprises a brick and stone engine and boiler house, containing one Worthington and two Deane steam pumps.

The Worthington engine, erected in August, 1877, is a compound, duplex, condensing engine, with 29-inch high pressure and 50-inch low pressure cylinders, and 30-inch pumps, all of 50-inch stroke. The engine is rated at 500 horse-power, and has a pumping capacity of 10 million gallons daily.

The Deane engines are duplicates of each other, and are compound, duplex, condensing engines, with 30-inch low pressure and 16-inch high pressure cylinders and 17-inch pumps, all of 24-inch stroke. They are rated at 150 horse-power each, and have each a pumping capacity of 3 million gallons daily. The Deane engines were erected in 1884. The three engines pump into the same force main.

There are 4 horizontal tubular boilers, similar in size and construction, each having 67 flues, 4 inches in diameter and 16 feet long, and single furnaces 5 by 6 feet and 31 inches high, giving 30 square feet of grate surface. The boilers were built by the Phœnix Foundry and Machine Company, two of them in 1876 and two in 1877. Their capacity is given as 100 horse-power each. Air is forced under the boilers by a No. 38 Sturtevant independent engine and blower.

The water is taken from Onondaga Creek at 30 feet below canal level and pumped 1,700 feet through two 30-inch cast-iron pipes to the distributing reservoir constructed in 1870. The elevation of the top of the reservoir banks is 119 feet above the water surface in the Syracuse level of the Erie Canal. Owing to the poor condition of the banks, the reservoir is never filled higher than 110 feet above the canal, or 9 feet lower than the top of the banks. At this elevation (110 feet), the reservoir holds about 50 million gallons. Its area is about 15 acres. The water from the original springs, used since 1829, is conducted into this reservoir. At Onondaga Hill, two miles southwest of the pumping station, there is a collecting reservoir on Furnace Brook, with a water-shed of $2\frac{1}{10}$ square miles. The high-water mark is 461 feet above the canal, and it holds 176 million gallons. The water from this reservoir is conveyed 2.4 miles by a 12-inch cement pipe to another small reservoir, holding 6½ million gallons, 800 feet west of the distributing reservoir. Its water surface is 165 feet above the canal. A pipe from this reservoir supplies the Idiot Asylum and portions of the westerly section of the city and is also so connected that water can, if desired, be turned into the service supplied from the lower reservoir.

The street mains are of cast iron and cement lined sheet iron pipe, and are generally supplied with water from the distributing

reservoir, which has a head of 110 feet above the surface of the canal. No record appears to have been kept by the company of the location, amount and size of the cement lined pipe laid. As far as can be ascertained by inquiry among the citizens, they are laid in Warren, Mulberry and Madison Streets, and perhaps in other streets. The water company having no maps of the distribution, I had a survey made of the streets, from which, and from information furnished by residents on the lines of pipe, the accompanying map (Plate 11) and tabular statement (Table VI.) of the distribution system have been prepared.

The total length of street mains obtained by measurement is $37\frac{11}{100}$ miles, in sizes and lengths as follows:

24 inch	1.93	miles.
16 "	0.36	"
12 "	4.41	"
10 "	0.83	"
8 "	4.09	"
6 "	10.85	"
4 "	14.64	"
Total	37.11	miles.

Connected with the mains are 387 fire hydrants, distributed as follows:

24	in the	1st	Ward.	51	in the	7th	Ward.
31	"	2d	"	41	"	8th	"
43	"	3d	"	15	"	9th	"
61	"	4th	"	0	"	10th	"
64	"	5th	"	0	"	11th	"
57	"	6th	"				

In response to a request for complete data regarding the Water Company's plant, the following letter was received from the President:

SYRACUSE, N. Y., January 2, 1889.

To the Honorable the Board of Special Water Commissioners:

GENTLEMEN:

On Monday, December 31, this company received a verbal request from you through Assistant Engineer Hill, for a statement having reference to the extent and cost of the plant of the Syracuse Water Company. The request is made, we suppose, pursuant to that section of the law constituting your honorable

board, which says: "They also shall inquire into the availability of the present water-works in said city, as a part of such system which they may recommend, and an estimate of the present value thereof, and shall include the same in this report."

We have the honor to comply with your request as follows: *First*, Availability: The plant of the Syracuse Water Company comprises about forty-three miles of mains, with the necessary gates and fixtures, etc. The mains are of graded sizes, according to the needs of the localities in which they are placed, ranging from four to twenty-four inches. These mains are connected with three reservoirs having a storage capacity of 225 million gallons. These reservoirs are of comparatively recent construction, and all are in first-class order except one, which requires a small expenditure of money to stop slight leaks when it is full. Otherwise their condition is above criticism. The pumping station is supplied with one Worthington pump with ten million capacity, and two Deane pumps of three million each, making a total capacity of sixteen millions. The battery of four boilers and appurtenances are complete and all in the best condition. The station building, constructed of brick and stone, is in thorough repair. The street mains, except less than four miles of them, are of iron of standard weight for a pressure of 175 pounds to the square inch and all are in good order and condition. Connected with the system in an experimental way, so designed as to make it permanent, is a section of gang wells at Onondaga Valley, with the necessary boilers, pumps and machinery to operate them.

Our plant, exclusive of that at Onondaga Valley, is "available" to the extent of 16 million gallons per day when supplied by the pumps, or for such demand as may be made upon the reservoirs.

Second, Value: The actual amount of money expended in the construction of this plant at this date is $773,948.87. In this amount not a dollar of the cost of repairs and maintenance is included. The capital stock of the Company is $572,000, about $202,000 less than the actual cost of the works. The Company has a bonded (debenture) indebtedness of $200,600. The stock

and bonds are almost entirely held by people of this city, largely in estates, for the benefit of women and children.

But the construction account does not show the actual present value of the plant.

Connected with the pumping station and distributing reservoir is about forty acres of land, the value of which has largely increased since its purchase years ago. There is also to be added the great value of rights and privileges secured to the Company by its franchises, such as the ownership of numerous springs and supplies. And a general market value based upon earnings, enters into the calculations. The cost of plants of various kinds is many times far below their actual value.

A basis for estimating the value of the works, should the city desire to possess them, may be found in the twenty-ninth section of Act Chapter 224, of the Laws of 1849, to which your attention is respectfully called.

We have the honor to be,

Very respectfully yours,

THE SYRACUSE WATER COMPANY,

By D. H. BRUCE,

President.

CHAPTER 224, OF THE LAWS OF 1849, SECTION 29.

The Common Council of the City of Syracuse shall have the right at any time after the expiration of twenty years to resume all the property, right, powers and privileges of the said Syracuse Water Company on paying to said Company the amount of capital stock actually paid in and expended in said works, with fifteen per cent. annually thereon, deducting therefrom the actual profits annually received by said Company, and on such resumption and payment by the Common Council, all the property, rights and privileges and powers of said Company shall vest absolutely in the Common Council of the City of Syracuse, and the said Company shall, by an instrument in writing, duly executed by the president and secretary of said Company, convey to said Common Council all the said property of said Company in said water works.

The question of the quality of the water to be furnished, is of equal importance with that of the quantity.

None of the analyses of the water which are available for the Syracuse supply, which I could find on record, gave a satisfactory basis of comparison. Made by several different chemists at different times, by different methods and expressed in different terms, the results given are simply confusing and lead to erroneous conclusions.

I have had therefore a series of analyses of all the waters considered made by Professor H. B. Cornwall of the John C. Green School of Science at Princeton, N. J. The samples of water were collected in glass demijohns of two gallons each, and transmitted to him with a statement of the character of the sources whence they were taken.

Accompanying his report is a full statement of the methods of analysis and the interpretation to be put upon results. This valuable paper is appended to this report.

During the progress of his investigations some of the results which he reported to me were so at variance with the information which had been furnished from other sources that I deemed it best to obtain corroborative statements from other reliable chemists, and I therefore submitted samples of the several waters to Dr. Charles Harrington of Boston whose large experience as one of the Analysts of the State Board of Health of Massachusetts entitles his opinions to great confidence.

From his partial reports, agreeing in the main with Professor Cornwall, I felt that a still further examination was desirable, and I had therefore a biological examination made by Dr. C. G. Currier of New York, whose experience in connection with Dr. Prudden, in this branch of investigation, in which there are only a few experts in this country, has been very extended.

As a further precaution, I submitted fresh samples of the waters, taken at the same time with Dr. Currier's samples, to Prof. Elwyn Waller of the School of Mines Columbia College, the well known analyst for the New York City Board of Health.

The reports of these gentlemen are as follows:

TABLE I. ANALYSES OF WATERS FROM THE VICINITY OF SYRACUSE, N. Y.

BY PROF. H. B. CORNWALL.—DECEMBER, 1888.

No.	Source.	Date.	Parts in 100,000.										Deposit.	Color.
			Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Nitrogen as Nitrates.	Oxygen Consumed.	Hardness.		Solids.				
								Before Boiling.	After Boiling.	Loss on Ignition	Mineral Matter.	Total solids.		
1	Skaneateles Lake.....	Sept. 7	0.004	0.008	0.43	none	0.06	9.3	2.9	0.3	12.2	12.5	Considerable brown film-like sediment	None.
2	Gang Wells.....	Sept. 8	0.003	0.003	4.7	0.28	0.02	32.0	17.0	4.0	59.3	63.3	Traces.	None.
3	Syracuse Water Co.....	Sept. 10	0.005	0.005	2.6	none	0.08	33.7	19.0	5.0	55.7	60.7	Very slight	None.
4	Oneida Lake.....	Sept. 10	0.008	0.015	0.4	none	0.37	9.4	7.8	1.7	13.1	14.8	Very little	Slightly yellowish.
5	Seneca River, above Baldwinsville.....	Sept. 14	0.014	0.021	4.3	none	0.28	14.5	7.5	4.0	26.7	30.7	Very little	Very slightly yellow-
6	Onondaga Creek at Cardiff	Sept. 13	0.007	0.004	0.6	none	0.10	18.1	5.6	0.3	24.5	24.8	Very little	None. [ish.
7	Otisco Lake.....	Sept. 13	0.006	0.016	0.43	none	0.18	9.6	4.8	0.6	12.4	13.0	Very little	None.
8	Salmon River.....	Sept. 28	0.009	0.008	0.36	none	0.30	4.3	...	0.71	6.39	7.1	Very little	Slightly brownish.
9	Gang Wells.....	Oct. 23	0.002	0.005	3.0	0.34	0.03	48.5	29.7	6.0	82.1	88.1	Very little	None.
10	Onondaga Creek, opposite Gang Wells.....	Oct. 23	0.005	0.007	0.6	none	0.16	24.3	7.7	0.6	42.4	43.0	Very little	None.
11	Green Lake.....	Oct. 29	0.016	0.012	0.5	none	0.11	10.8	8.0	0.5	15.9	16.4	Very little	None.
12	Lake Ontario.....	Nov. 28	0.004	0.019	4.2	none	0.37	12.0	7 1	1.3	25.0	26.3	Little	Slightly yellowish.

REPORT OF PROF. H. B. CORNWALL.

JOHN C. GREEN SCHOOL OF SCIENCE,
COLLEGE OF NEW JERSEY.

PRINCETON, N. J., December 18th, 1888.

No. 1. Skaneateles Lake. The chemical analysis shows this water to be organically quite pure for a lake water. The moderate hardness is nearly all due to carbonate of lime, and could, if necessary for special purposes, be greatly reduced by the judicious use of lime. The water deposits, after standing some weeks in the demijohn, a very considerable, filmy, brown sediment, apparently of purely vegetable growth.* This might cause trouble in the mains. Its origin is not easy to determine, in view of the analysis, but the fact requires consideration.

No. 2 Ground Water, valley of Onondaga Creek. This water is remarkably free from organic impurity, but its great hardness constitutes a serious objection. It is doubtful whether there would be any profit in reducing the temporary hardness by the use of lime, since the permanent hardness would still amount to something like 20 per 100,000.

No. 3. Hydrant water, Syracuse Water Co. (from Onondaga Creek). This water would also constitute an excellent supply, were it not for the hardness and large total solids.

No. 4. Oneida Lake. This is not a bad water, as regards organic impurity, but it is somewhat doubtful in that respect. The impurity may be only of vegetable origin, but even in that case its extent is such that the possible variations in amount at different times of the year should be carefully studied before adopting it as a general supply.

No. 5. Seneca River. The same remarks apply to this water as to No. 4, but with greater force. Indeed, it might be said, from a chemical point of view, that this water was positively a bad water, owing to the large amounts both of free and albumi-

* [This sample was taken from near the north end of the lake, with the wind blowing from the south and making the water quite turbid where it was shallow. Other samples taken in deep water some distance out did not have any sediment. (See the other analyses.) J. J. R. C.]

noid ammonia. The rather large amount of chlorine may be due to the geological conditions of the stream, as shown by the considerable hardness.

No. 6. Onondaga Creek, site of proposed Cardiff Dam. Organically this water is of very fair quality, decidedly better than constitutes the supply of many of our largest cities. The hardness is great, but not such as to preclude its use even in its present condition. For special purposes the hardness could easily be reduced to a very moderate amount by the use of lime.

No. 7. Otisco Lake. This water also is organically of fair quality. Unless there is reason to fear an increase of organic impurity at different seasons this water might be depended upon as satisfactory for all general purposes. It is much like No. 1, but seems inferior in organic purity. A careful study of the surroundings of the lake should be made, since the free and albuminoid ammonia are high enough to cause some suspicion of other than vegetable impurity.

No. 8. Salmon River, at site of proposed Reservoir. This water contains much organic matter, but the indications are that it is of vegetable origin and not of a dangerous character. There is often, however, danger that such matter may in time cause troublesome growths or deposits in the distributing pipes or mains. It does not seem to be one of the most promising samples.

No. 9. Same source as No. 2. Organically this is a very pure water. The total solids are nearly 50 per cent. greater than in No. 2, and the hardness is also greater in about the same proportion. The temporary hardness does not vary proportionately with the total hardness, and the only conclusion is that this water supply is of variable character. If the hardness shown by No. 9 is likely to continue it would preclude consideration of this as a general water supply. More will be said about this question. (See pages 72–74.)

No. 10. Onondaga Creek, opposite Wells. As regards organic impurity this is a very fair water, much like No. 6. The hardness would be too great for a general supply unless reduced, but as the temporary hardness is the principal difficulty this evil might be remedied.

No. 11. Green Lake. Judged by the usual standards for free and albuminoid ammonia, this water would be regarded as very suspicious. Although the "oxygen consumed" is not large, yet the impurity may be only of vegetable origin. In that case the large free ammonia may be due only to decaying vegetable matter, and in that case would probably be less at other seasons of the year. The same conditions, however, which give rise to these indications of organic contamination might also cause disagreeable odor or taste in the water.

No. 12. Lake Ontario. The remarks made on No. 4 with regard to organic impurity apply also to this water. It is no worse in that respect than the supplies of some of our large cities, but in such cases complaint is often made against the water at different times. This is generally based on the appearance of vegetable growths in the water, which may not be injurious to health, but often give rise to unpleasant odor or taste. It is very likely that similar conditions will arise in regard to No. 12. The hardness is not too great. The chlorine seems high for so large a lake, and unless accounted for by geological causes would be a ground for suspicion. On the whole this is not a promising water.

H. B. CORNWALL.

TABLE II.

ANALYSES OF WATERS FROM THE VICINITY OF SYRACUSE, N. Y.

BY CHARLES HARRINGTON, M. D.—DECEMBER, 1888.

No.	Source.	Date.	Parts in 100,000.								Odor.	Color.	Appearance.
								Solids.					
			Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Nitrates.	Hardness.	Volatile Residue.	Fixed Residue.	Total Residue.			
A	Gang Wells	Oct. 29	0.0062	0.0036	2.76	None	32.0	17.6	63.7	81.3	None	None.	Clear.
B	Salmon River	Nov. 5	0.0028	0.0208	0.15	None	1.5	4.3	2.2	6.5	None	Brownish	Clear.
C	Otisco Lake	Nov. 5	0.0054	0.0166	0.23	None	6.5	6.1	7.8	13.9	None	None	Clear.
D	Skaneateles Lake	Nov. 12	0.0034	0.0118	0.31	None	8.0	2.8	11.8	14.6	None	None	Clear.
E	Oneida Lake	Nov. 12	0.0040	0.0240	0.24	None	8.0	5.9	11.5	17.4	None	None	Somewhat turbid.
F	Onondaga Creek at Cardiff	Nov. 26	0.0028	0.0058	0.29	None	14.0	3.1	19.9	23.0	None	Very light brown	Very slight opalesence.
G	Lake Ontario	Nov. 28	0.0036	0.0207	3.69	None	10.5	7.8	14.9	22.7	Faint	Brownish	Slightly turbid.

REPORT OF CHARLES HARRINGTON, M. D.

HARVARD MEDICAL SCHOOL,
CHEMICAL LABORATORY,

BOSTON, December 3d, 1888.

Of these seven samples, the first, A, Gang Wells, is clearly unfit for domestic or manufacturing purposes on account of the very large amount of mineral matter which it contains. The fixed residue is chiefly sulphates and carbonates, the former appearing to predominate.

Sample B, Salmon River, contains a small amount of mineral matter and is very soft and therefore suitable for boilers. The organic matter is vegetable in character. Proper storage would doubtless improve this water as a source of supply.

Sample C, Otisco Lake, contains less organic matter than B, but is harder. The hardness, however, is not sufficient in amount to stand in the way of acceptance.

Sample D, Skaneateles Lake, is slightly harder than C, and contains less organic matter. The remark as to hardness applies as with C. In the fixed residue the carbonates appear to predominate.

Sample E, Oneida Lake, can hardly be considered as a good water on account of the amount and character of the organic matter. It is possible, however, that this water would improve with storage. This sample contains very numerous living organisms (Entomostracæ). The fixed residue contains considerable sulphates.

Sample F, Cardiff, is very free from organic matter but has considerable hardness, which from both a domestic and manufacturing standpoint is an objection. The degree of hardness is however by no means excessive, and, other things being favorable, need not be considered as a serious obstacle. In the fixed residue the carbonates appear to predominate.

Sample G, Lake Ontario, appears rather suspicious and is very inferior to the others in several respects.

It is of course a difficult, and often impossible task, to form

a correct judgment of the relative value of water samples from merely chemical data unaided by other considerations. From a chemical standpoint I should be inclined to rule out of further consideration the samples from the Gang Wells, Oneida Lake and Lake Ontario.

The samples from Otisco and Skaneateles Lakes I should consider as very fair for domestic and manufacturing purposes.

The sample from Salmon River, with proper storage, appears to be on the whole the best for all purposes of a public supply, although organically the sample from Cardiff is far superior.

It is unfortunate that the Cardiff water should have fourteen degrees of hardness for otherwise it is all that could be desired. I would by no means condemn it on this account, for a matter of fourteen degrees of hardness may very well be outweighed by other considerations.

CHARLES HARRINGTON, M. D.

TABLE III. ANALYSES OF WATERS FROM THE VICINITY OF SYRACUSE, N. Y.

BY PROF. ELWYN WALLER, PH. D.—DECEMBER, 1888.

No.	Source.	Date.	Parts in 100,000											Odor.	Color.
			Chlorine in Chlorides.	Phosphates.	Nitrites.	Nitrogen in Nitrates and Nitrites	Free Ammonia.	Albuminoid Ammonia.	Hardness. Before Boiling.	Hardness. After Boiling.	Solids. Organic and Volatile.	Solids. Mineral Matter.	Solids. Total Solids by Evaporation.		
A[2]	Gang Wells.....	Nov. 26	1.633	none	none	0.288	none	0 0010	60.79	39.65	8.00	78.50	86.50	Faint	Clear light blue.
B[2]	Salmon River.....	Nov. 22	0.107	Faint trace	Faint trace	0.053	0.0262	0.0158	3.110	0.46	2.50	3.00	5.50	Slight woody	Clear greenish brown.
C[2]	Syracuse Water Co...	Nov. 23	1.100	Faint trace	none	0.119	0.0030	0.0020	39.13	19.93	8.00	41.00	49.00	none	Greenish faint brown tinge
D[2]	Skaneateles Lake.....	Nov. 23	0.319	none	none	0.068	0.0030	0.0040	10.21	0.71	1.70	10.30	12.00	Faint	Clear light blue.
E[2]	Oneida Lake.....	Nov. 23	0.231	none	none	0.006	0.0026	0.0164	11.20	3 95	3.70	9.30	13.00	none	Clear bluish green.
F[2]	Onondaga Creek at Cardiff.....	Nov. 26	0.195	none	none	0.099	none	0.0030	18.95	2.10	3.50	19.00	22.50	none	Clear bluish green.
G[2]	Lake Ontario.....	Dec. 6	3.621	none	Very faint trace	0.0236	0.0028	0.0028	14.86	5.16	5.00	20.50	25.50	none	Slightly turbid yellowish green.

TABLE IV. ANALYSIS OF MINERAL MATTER IN WATERS FROM THE VICINITY OF SYRACUSE.

BY PROF. ELWYN WALLER.

	Skaneateles Lake.	Cardiff.	Salmon River.	Oneida Lake.	Lake Ontario.	Syracuse City Supply.	Gang Wells.
Calcium Chloride	0.383	....	...	....	....	....	...
Sodium Chloride	0.123	0.322	0.175	0.380	5.967	1.813	2.691
Potassium Sulphate	Trace	Trace	Trace	Trace	Trace	1.573	7.136
Calcium Sulphate	0.497	2.074	0.289	4.811	5.457	19.205	42.192
Calcium Carbonate	6.533	12.260	....	1.893	6.952	13.192	16.923
Magnesium Carbonate	2.310	4.462	0.870	2.572	3.496	6.688	10 141
Alumina and Oxide of Iron	0.070	0.210	0.070	0.100	0.200	0.200	0.100
Silica	0.350	0.850	0.530	1.300	0.920	1.150	1.100
Total Mineral	10.266	20.178	3.464	11.056	22.992	43.821	80.283
Total solids (by evaporation)	12.000	22.500	5.500	13.000	25 500	49.000	86.500
Organic Matter (difference)	1.734	2.322	2.036	1.944	2.508	5.179	6.217

REPORT OF ELWYN WALLER, Ph. D.

SCHOOL OF MINES,
COLUMBIA COLLEGE.

NEW YORK CITY, December 17th, 1888.

I am constrained to consider the samples submitted as fair average specimens of the waters designated, though as to two of them I must make a remark. Sample B (Salmon River) contains large amounts of organic substance of objectionable character, which is no doubt derived from rotting vegetation incident to the season of the year, and probably represents that water at its worst.

Sample G (Lake Ontario) cannot be a fair representative of the quality of water in Lake Ontario. It apparently contains sewage or drainage from some point on the shore. The analyses on record of Lake Ontario water, to which I have been able to refer, show chlorine 0.3 to 0.5 ; total solids, 10 to 13. This sample shows chlorine 3.621 ; total solids, 25.5, and in other respects also shows an inferior quality.

Considering the waters separately, the conclusions would be as follows :

A—Gang Wells, Onondaga Creek, free from sewage or other contamination of that character, but contains too much lime, salt and solids generally to be admissible for either household or manufacturing purposes.

B—Salmon River, contains much organic matter of objectionable quality for household uses. For use in boilers it is quite possible that the organic matter might prove detrimental. For other technical purposes its color might constitute a serious objection.

C—Syracuse City water. Apparently free from sewage, etc. The "hardness" is beyond the limits ordinarily allowed for waters of good quality, while the solids are on the limit. Unsuited for boiler and manufacturing purposes.

D—Skaneateles Lake. Of good quality both for domestic and manufacturing purposes.

E—Oneida Lake. Similar to the last, but inferior in respect to nitrogenous constituents and hardness, especially "permanent" hardness, recorded as "hardness after boiling."

F—Onondaga Creek at Cardiff. Sewage contamination apparently absent. Might be used for domestic purposes though the hardness is considerable and is on the extreme limit allowed for use in boilers, etc.

G—Lake Ontario. Quality for domestic purposes open to suspicion. Usable for boiler and manufacturing operations.

In comparing these waters for boiler and manufacturing uses, the order of quality is practically the order of their hardness. The magnesium compounds are such that they are likely to give but little trouble in the matter of attacking the iron of the boilers, and the inclination to form "scale" is chiefly to be measured by the "permanent hardness." I must reiterate my doubt as to the usability of the Salmon River water on account of the character of the organic substance which it contains, though in that respect I may be mistaken. With this qualification I would place them in this order:

	Permanent Hardness.	Temporary Hardness.	Total Hardness.	Total Solids.
B—Salmon River.	0.46	2.65	3.11	5.5
D—Skaneateles Lake.	0.71	9.50	10.21	12.0
E—Oneida Lake.	3.95	7.20	11.20	13.0
G—Lake Ontario.	5.16	9.70	14.86	25.5
F—Onondaga Creek at Cardiff.	2.10	16.95	18.95	22.5
C—Syracuse City Supply.	19.93	19.20	39.13	49.0
A—Gang Wells.	39.65	21.14	60.79	86.5

The last two (C and A) are unsuited for boiler and manufacturing purposes.

For sanitary and domestic uses, I should class them as follows:

D—Skaneateles Lake.

E—Oneida Lake.

F—Onondaga Creek at Cardiff.

C—Syracuse City Supply.

A—Gang Wells, Onondaga Creek.

B—Salmon River.

G—Lake Ontario.

The last three should be excluded from consideration (A, B and G) on account of properties already mentioned.

If we consider both sanitary and manufacturing uses for these waters, the order would be the same as that just given, but C should also be included among those not worthy of consideration in this relation. F is so near the limit usually given for hardness in a first-class water, that its use cannot be recommended if water of a better quality can be obtained. The fact, however, that a very large proportion of the hardness is "temporary" (removable by boiling) is a point in its favor.

E. WALLER, Ph. D.

INTERPRETATION OF THE ANALYSES.

It will be observed that all three of the chemists unhesitatingly condemn the water of the gang wells as unfit for domestic or manufacturing purposes, in consequence of its excessive hardness and the large amount of mineral matter it contains. The very large proportion of sulphates in this water renders it peculiarly unfit for use in boilers.

In this connection I have examined three analyses of water from the gang wells submitted to me by Mr. Dwight H. Bruce, the President of the Syracuse Water Company, and Mr. Joseph Edwards, the owner of the pumping plant at the wells, and which they consider contradictory to the analyses I have given above. These analyses were made at the request of the Water Company, by two chemists of acknowledged eminence, Professor Charles F. Chandler of the School of Mines of Columbia College, and Professor S. A. Lattimore of the Rochester University.

It appears from the statements made and documents submitted by Mr. Bruce and Mr. Edwards that in February, 1888, when the first test of the gang wells was made, samples of the water were analyzed by Professors Chandler and Lattimore. Professor Chandler's analysis showed the water to be very hard, and the quantity of lime and sulphuric acid great. His written opinion did not touch on the suitableness of the water for boiler

and laundry use, but only said that it was pure and free from contamination. Professor Lattimore reported that the hardness was chiefly due to carbonates of lime and magnesium and the sulphates were present only in insignificant quantities. Here is a very material discrepancy to start with.

On November 1, 1888, just before the last test of the wells was stopped, Mr. Bruce sent a sample of the water to Professor Lattimore who analyzed it and reported that the sulphates were present only in very small proportions. In neither analysis did he report the hardness. Mr. Edwards states that in the sixty-day run of the pumps the boilers were supplied with well-water and that the scale formed was insignificant in amount and not seriously objectionable in kind.

As to the organic purity of the water all agree. As to the mineral constituents, the points of agreement and difference can be best understood by arranging the results in tabular form, thus:

	PARTS IN 100,000.						
	Lattimore. Feb. 1, 1888.	Chandler. Feb. 1, 1888.	Cornwall. Sept. 8, 1888.	Cornwall. Oct. 23, 1888.	Harrington. Oct. 29, 1888.	Lattimore. Nov. 1, 1888.	Waller. Nov. 26, 1888.
Total Solids	57.00	58.00	63.30	88.10	81.30	64.00	86.50
Loss on Ignition	13.60	1.50	4.00	6.00	17.60	23.00	8.00
Fixed Residue	43.40	56.50	59.30	82.10	63.70	41.00	78.00
Chlorine	5.43	5.49	4.70	3.00	2.76	4.20	1.63
Total Hardness	.....	30.18	32.00	48.50	32.00	.....	60.79
Permanent Hardness After Boiling	.....	24.42	17.00	29.70	.....	.....	39.65
Lime Ca O	.....	16.81	17.90	26.74	.....	.....	26.85
Sulphuric Anhydride SO_3	.....	14.45	16.01	28.76	.....	.....	28.10
Carbonate of Lime Ca CO_3	.....	18.05‡	16.75	20.75	.....	.....	16.92
Sulphate of Lime Ca SO_4	.....	24.56‡	20.69	36.72	*	†	42.19

* Sulphates predominate. † Sulphates insignificant. ‡ Computed.

Examination of this table leads very clearly to the conclusion that the ground-water, when undisturbed by pumping, was about the same in September as it had been in February. It was very hard, and the hardness was largely due to sulphates of lime. The analyses of Chandler in February, and Cornwall in September, are as close as two chemists are ever likely to agree on the same water.

When the underground water was disturbed by the pumping the character of the water changed. The new water which came down from the upper part of the valley was harder and more charged with sulphates, probably from beds of gypsum, and the farther it came to fill up the void in the gravel caused by the pumping, the harder and more sulphurous it became. The increase of hardness was due almost entirely to the increased amount of sulphates.

Professors Chandler, Cornwall, Harrington and Waller agree that the sulphates predominate in causing the hardness.

I submitted the later analyses to Professor Lattimore and inquired how they could be harmonized with the results obtained by him, and he replied that the differences in the results were such as to prove conclusively, in his opinion, that the samples of water were not identical.

It is impossible that a water so surcharged with sulphates of lime and potassium, as the later analyses showed the water which came last to the pumps to be, should not be injurious to boilers and unfit for any use.

But if this water should be considered fit to use, it would be necessary to pump it directly into the mains and not allow it to be stored in an open reservoir, for the invariable experience of all towns which have been supplied from underground water is that it rapidly becomes foul and offensive and swarms with vegetable growth, when exposed to the air in open reservoirs. It must be used quickly, just as it comes from the ground.

The analyses all agree that the water furnished by the Syracuse Water Company is very undesirable for domestic and manufacturing uses. The testimony of users of the water is very strongly to that effect.

The water of Lake Ontario is also condemned by all the examiners as containing too much solid residue, too large a proportion of organic matter, too much chlorine and too many living organisms.

The water of the Seneca River is also shown to be decidedly unfit for use, and the water of Green Lake is not satisfactory according to Prof. Cornwall's analysis.

As to the remaining samples, the opinions expressed as to their relative standing are somewhat divergent.

But on comparing and analyzing the figures given by the several examiners, there appears a remarkable harmony in the results obtained by them, considering that their investigations were pursued independently and the samples of water procured at different times. The actual quantities of the several constituents vary, it is true, according to the method of determination used by each chemist, but the relative standing of the different waters, from the chemical standpoint, is very nearly the same in each set of analyses. Perfect agreement of actual quantities is not to be expected in analyses by different operators, the quantities themselves being so small that a very slight difference in method of manipulation may produce considerable difference in results. But where the results are so harmonious in themselves, and where, as is the case in these analyses, differences, in most cases, accord with what might be expected under the conditions, the conclusions to be drawn from the analyses may be accepted with a good deal of confidence.

Table V. presents the details of all the analyses in compact form and the average of the results obtained by the different chemists.

In order to properly interpret these results, it is first necessary to understand exactly what a chemical analysis of water indicates with reference to the value of that water for domestic and manufacturing purposes, and how far such analysis determines whether the water is likely to produce or foster disease.

In the present state of chemical science, the most careful and experienced investigators base their judgments upon experimental knowledge. Instead of endeavoring to prove that in consequence of the chemical action of certain constituents in a water, such water must produce certain effects on the persons using it, they examine critically the waters in use where certain unsanitary conditions are known to exist and strive to discover wherein those waters differ from those in use where the specific conditions complained of do not exist.

A number of points of difference have been from time to time discovered by different observers, but the further attempt to

apply these results to cases in practice, has led to the abandonment, one after another, of the ideas that those particular differences could be relied upon as affording a sure criterion of the unsanitary qualities of a water.

The theory which has so far best stood the test of experience is that of Wanklyn, an English chemist, that the presence of a certain proportion of what is termed "Albuminoid ammonia" in a water, is almost certain to be followed by an unhealthy condition in the users of that water. It was supposed by the originator of this test, that the injurious condition of the water was due to animal pollution, and when it was found that a considerable proportion of albuminoid ammonia was present at certain seasons in mountain streams flowing through districts nearly or entirely uninhabited, the opinion was expressed by most chemists that the supposition that the presence of that constituent was unhealthy, was unfounded.

The investigations however of Dr. Charles Smart, of the U. S. Army Medical Corps, and of other distinguished members of that corps, have conclusively shown that the decomposition of vegetable matter produces similar effects to the decomposition of animal matter, and that in the wild mountainous regions of the Western States a malarial fever follows the use of water in which over 0.016 parts of albuminoid ammonia are found to each hundred thousand parts of water. In the words of Dr. Smart,* "Variations in the organic impurity of the water were shown to correspond with variations in the intensity and prevalence of the disease.

"As animal matter, in certain stages of its decomposition or enveloping specific germs, gives expression to its presence in the system by the development of typhoid fever, so vegetable matter, in certain stages of its decomposition or enveloping specific germs, gives rise to an adynamic remittent, for which the writer has suggested the name of aquamalarial fever.

"Viewed in its connection with this affection, the organic ammonia should not exceed .016 parts, for, when .020 is reached, the disease makes its appearance and becomes more pernicious in

*Buck's Hygiene, Vol. II., p. 130.

individual cases as the amount increases. Not that aquamalarial developments are to be expected in every case where the organic ammonia exceeds this limit, but that experience shows a greater probability of their occurrence with a water thus impregnated,—malaria being more likely to be present with a large than with a small vegetable contamination."

The established rule now among water analysts is that in any water the presence of .010 parts of albuminoid ammonia renders the water suspicious and .015 parts are enough to condemn it as absolutely unsafe.

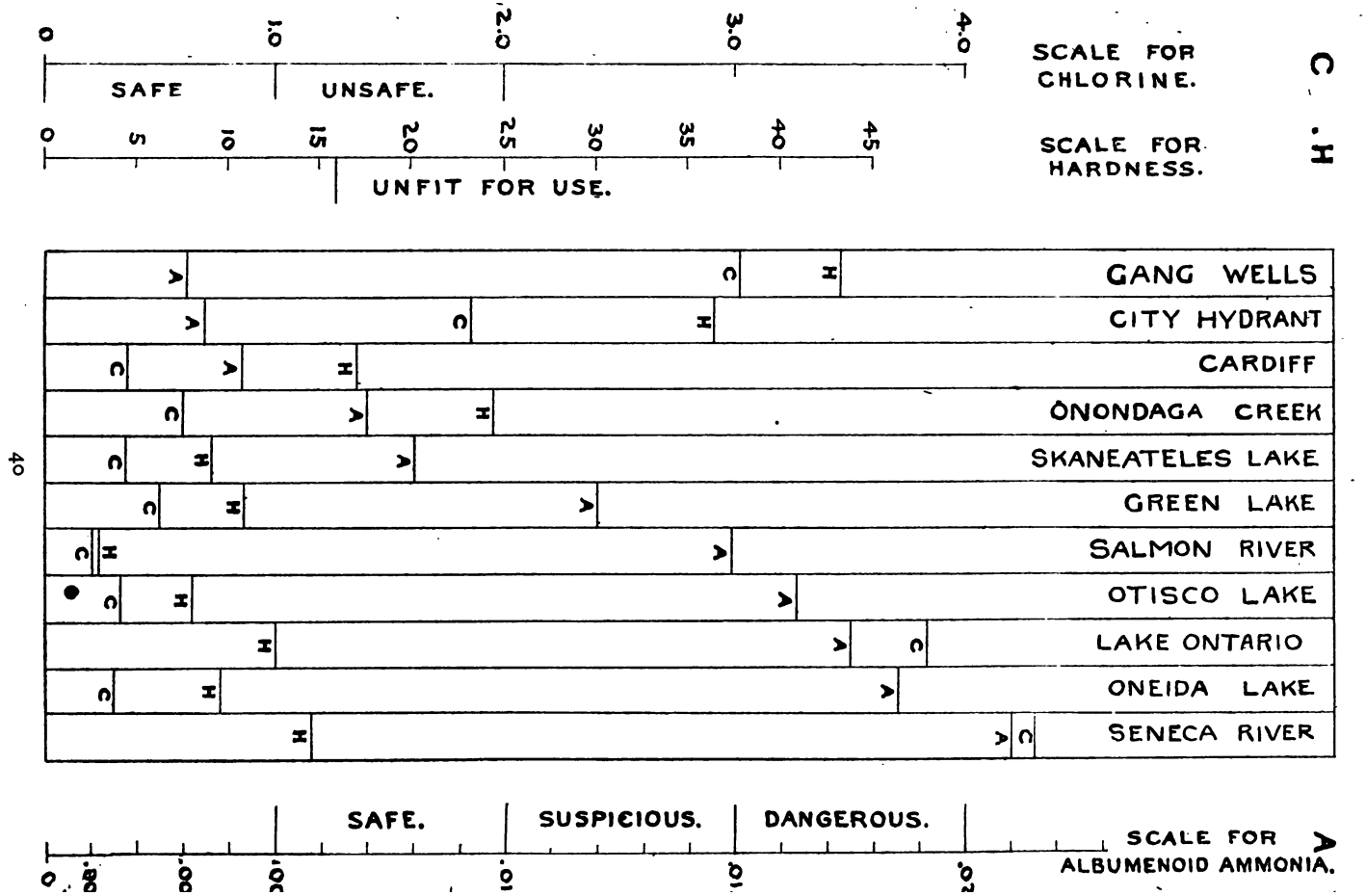
In connection with this test, that of measuring the amount of oxygen which a water will consume, is deemed valuable. If a water contains decomposing organic matter it will absorb more oxygen than a purer water, and while this test is not an infallible one, it is employed to obtain corroborative evidence in the case of a doubtful water, the absorption of more than 0.15 part showing it to be suspicious and of more than 0.21 part being sufficient to condemn it.

Still another test for the relative purity of waters is found in the proportions of chlorine they contain. As Professor W. R. Nichols says in his work on water analysis, "the presence of any noticeable amount of chlorine, say much more than 1 part in 100,000, indicates contamination from human sources. Chlorides remain as evidences of past contamination after all other evidences have ceased to exist."

Examining then, the analyses, specially with relation to constituents which are classed as affecting the health of those using the waters, the average of all tests is as follows:

PARTS PER 100,000.

		Free Ammonia.	Albuminoid Ammonia.	Chlorine.	Oxygen Consumed
1	Gang Wells	0.0028	0.0031	3.023	0.02½
2	City Hydrant	0.0040	0.0035	1.850	0.08
3	At Cardiff. } Onondaga Creek {	0.0033	0 0043	0.362	0.10
4	At Wells. } Onondaga Creek {	0.0050	0.0070	0.600	0.16
5	Skaneateles Lake	0.0035	0.0080	0.353	0.06
6	Green Lake	0.0160	0.0120	0.500	0.11
7	Salmon River	0.0127	0.0149	0.206	0.30
8	Otisco Lake	0.0057	0.0163	0.330	0.18
9	Lake Ontario	0.0035	0.0175	3.837	0.37
10	Oneida Lake	0.0049	0.0185	0.290	0.37
11	Seneca River	0.0140	0.0210	4.300	0.28
	Suspicious Standard, more than	...	0.0100	....	0.15
	Dangerous Standard, more than.	...	0.0150	1.000	0.21


0
1.0
2.0
3.0
4.0
SAFE
UNSAFE.
SCALE FOR CHLORINE.
C
0
5
10
15
20
25
30
35
40
45
UNFIT FOR USE.
SCALE FOR HARDNESS.
H
40
GANG WELLS
CITY HYDRANT
CARDIFF
ONONDAGA CREEK
SKANEATELES LAKE
GREEN LAKE
SALMON RIVER
OTISCO LAKE
LAKE ONTARIO
ONEIDA LAKE
SENECA RIVER
SAFE.
SUSPICIOUS.
DANGEROUS.
SCALE FOR ALBUMENOID AMMONIA.
A

If then, there is any dependence to be placed upon the judgment of the distinguished chemists who have formulated the rules for determining the wholesomeness of waters, only two of the above waters can be considered as perfectly safe to use for domestic supply, those of Lake Skaneateles and of Onondaga Creek at Cardiff.

The chief objection to the Cardiff water, from the economic point of view, is its hardness. This, however, is largely due to carbonates, the proportion of sulphates which produce injurious scale in boilers, being less than in most of the waters examined, but more than in that of Skaneateles Lake. As Professor Cornwall estimates it, a million gallons of water from Skaneateles Lake would require to be treated with 690 pounds of crystallized carbonate of soda to make it entirely soft, while the Cardiff water would require 1,332 pounds and the Gang-well water 7,067 pounds.

The amount of chlorine present is sufficient to debar from consideration the water of the Gang Wells, the Syracuse Water Company's supply, Lake Ontario and Seneca River.

The proportion of albuminoid ammonia found, as confirmed by the oxygen test, shows the waters of Green Lake, Salmon River, Otisco Lake, Lake Ontario, Oneida Lake and Seneca River to be, in all probability, unfit to introduce for a domestic supply in their natural state.

The last three named are certainly not worth further consideration or discussion.

The waters of Green Lake, Salmon River and Otisco Lake give indications of being rich in decomposing organic matter beyond the safe limit, at the season at which the samples were taken, and if any effort should be made to use them, full provision ought to be made for thorough filtration and aeration sufficient to oxydize the objectionable constituents.

Biological Examination.

As above stated, a biological examination of some of the waters was made for the purpose of determining the relative quantity of living organisms in the several sources of supply at this season of the year.

While this does not, any more than chemical analysis, determine the absolute healthfulness of a water, in the absence of any recognized disease-producing bacteria, scientists affirm that, "other things being equal, richness in bacteria indicates organic impurity; scarcity of bacteria, organic purity." * If, however, there are a large number of bacteria of only a few species, and those not recognized as dangerous, and the chemical analysis shows purity, the water may be considered safe, but at the same time as more liable to pollution than a water equally pure chemically, in which few bacteria are found. The results of the examination I had made are set forth in the following report:

REPORT OF CHARLES G. CURRIER, M. D.

NEW YORK, January 17, 1889.

I herewith make a statement of the relative number of bacteria living in one cubic centimetre of each of the waters collected by me and by your assistants; several plates of all of these having been prepared with Koch's nutrient gelatine, all these having been made as quickly as possible in the immediate neighborhood of the source or in Syracuse with the exception of the first sample from Cardiff and the others marked with an asterisk(*). The interval between the collection and first plating varied from 2½ minutes to 3 hours. During this time and until after two or more other plates of each sample had been prepared for comparison and corroboration in the Laboratory in New York City, the water was kept, as nearly as possible, at the temperature of the body of water from which the sample was taken. The water was collected in sterilized bottles, and every known necessary precaution was taken to prevent contamination or the introduction of germs from without during all stages of the process of investigation.

One cubic centimetre is nearly equivalent to one-fourth of a teaspoonful. Hence, if 1 c. c. of a certain water contain 250 bacteria, one teaspoonful contains 1,000; which means that in a goblet holding eight fluid ounces there would be, when filled with such water, about 50,000 bacteria.

* Dr. W. T. Sedgwick, Jour. N. E. W. W. Ass'n., June, 1888, p. 12.

TABLE IV.

		In one cubic centimetre of each water the number of living bacteria developing in Koch's nutrient gelatine was: 1888. Nov. 23;	Dec. 6;	Dec. 30	Average	Number of distinct species of bacteria recognized and differentiated.
SKANEATELES LAKE...	From body of lake at outlet and centre..	39	21	.. . .	30	3
GANG WELLS	From steam and hand pumps.	317*	297	.....	307	5
SALMON RIVER	At fish-preserve, above second bridge.....	266	278	....	272	6
LAKE ONEIDA....	In body of lake, over ¼ mile away from South shore, wind blowing from other shore....	213	316	... ..	265	7
LAKE ONTARIO	Outside Oswego shore, in deep water, strong breeze blowing from the north.....	551*	648	.....	600	6
SYRACUSE HYDRANT...	From faucets in use in different parts of the city, water allowed to run freely before being taken....	483	491	.....	487	8
					Av. of last two	
ONONDAGA CREEK.....	At "Narrows," near proposed site of Dam	6,000*	1047	1278	1163	8
	From different points ½ mile to 2½ miles above Cardiff..	.....	443	1061	752	8

* The three samples indicated above by an asterisk [*] were collected by your assistants and sent to me, and the plates from which the estimates of these three were made were prepared only in New York City. Hence they were made and the culture of the bacteria was begun more than three hours after the collection of the waters. The Onondaga Creek sample was sent by itself and came slowly, and warmth in transit may have caused an increase.

To estimate the value of these figures, I give the numbers from the examination of some waters well known to civil engineers and hygienists :

	Bacteria.
Berlin analyses have been the most thorough of those of any city and therefore I give them for the last half of November and the first half of December, 1885, the latest accessible, taking the average of the water as delivered at five faucets in central parts of the city, weekly examinations having been made of each. Twenty examinations average, in 1 c. c	198
Croton examinations by me of water from hydrant in New York City in latter half of November and first half of December, 1888, at intervals of usually two days between the collections, show an average of	232
December 19, 1888, I found in Croton water	673
At times the Croton examination has shown a larger number of living bacteria than I have found in any of my examinations of the Syracuse samples.	
January 3, 1889, I found in Croton water	443
January 11, " " " " " "	593
January 12, " " " " " "	1,107
Poughkeepsie, December 25, 1888, Hudson River water, unfiltered	11,000
" " " " " " " filtered	5,300
There had been some rain and much melting of snow and this water was very turbid and was regarded by all as in an unusually bad state.	
East Orange, December 27, 1888. Average of wells supplying waterworks	34
This water flows from copious springs through fine natural filter. Received in immense wells. No dwellings near or other chance of contamination.	
New Haven—Lakes and brooks, November 29, 1888, average	42
These figures are not absolutely reliable, as this water was kept irregularly cold for 24 hours before examining and some bacteria may have perished.	
Highland Lake, December 25, 1888.—Highest number found	18
Three examinations made. This lake is about six miles below West Point, back from the river and 135 feet above its level. It is backed by mountains and fed by springs and is free from residences or other similar sources of contamination.	

Cochituate Lake supply in Boston (Back Bay district). Examination made by Mr. E. O. Jordan.

	Bacteria.
November 13, 1888 in 1 c. c	51
" 26, " in 1 c. c	146
December 31, " in 1 c. c	208

Wolffhügel, at the Berlin Health Bureau, received data from many districts of Germany and Austria. An inspection of these and a comparison with the reported analyses of the waters of other cities, together with a consideration of the reliable and accurate statistics of Plagge and Proskauer, make it seem advisable to consider no water as recommendable when one cubic centimetre of it taken from the hydrant has over 300 bacteria developing in gelatine. The same observers seem disposed to reduce the permissible average maximum to 150 per cubic centimetre taking the water after it has passed the Berlin filter and before it has entered the hydrant system. One water, reported by Professor Frisch (of Vienna) as generally regarded as a good drinking water, showed as many as 345 bacteria per cubic centimetre. Professor Fuerbringer (of Jena) reported as many as 256 bacteria in one water, which he was informed by all who used it, had always appeared eminently healthful. On the other hand, water was reported to Wolffhügel as having fewer than 50 bacteria, while considered objectionable by reason of excess of ammonia as shown by chemical examination. These exceptions, however, do not destroy the value of the standard given. Such standards as are here given are arbitrary and, judging merely from a slight excess in the number of bacteria, it is not fair to class a water as inferior. In waters there may be many bacteria which fail to develop in the prepared gelatine which is used for this purpose. So when I mention in the table that I recognize only a given number of species as constantly present in all the samples of a certain water, the value of that observation is chiefly relative as assisting to choose between two or more waters. The fewer the species, the better the water, wherever there is any chance of human or other pollution of it.

After determining the number, I have investigated very carefully to decide whether any harmful varieties of bacteria were present. If, among any of the varieties, there be one or more species which are clearly of a disease-producing kind, these render the water at best undesirable, and it is safe to say that, where there are chances of pollution from residences and other sources, the larger the variety of bacteria the more likelihood

there is of human contamination of the water. Rivers and lakes, whose drainage area is large and well-peopled, furnish water less desirable than that from underground sources or from lakes fed chiefly by deep springs.

Hygienically, the most important quality of a water is the presence or the absence of the infective matter—that in the water which, among those drinking it, may imperil life or in any degree impair health.

Chemistry as yet affords no certainty in this respect. The bacteriological test is of absolute value in only a small proportion of the cases of infective diseases which occur. This is partly because, even though the specific bacteria develop on our culture media, other and harmless bacteria may overwhelm the the slowly-developing, disease-producing kinds. Then, too, the infection may have disappeared before a doubtful water is examined.

The chief value of the bacteriological test seems to be that, though all of these minute organisms detected in a certain water may be harmless so far as is yet known, still they are the elements most nearly akin to those causative of certain more or less serious diseases and both flourish best under similar conditions of nutrition and environment. For instance, typhoid fever is a disease which scientific physicians regard as distinctly caused by a variety of bacteria of low vitality which can live and remain actively infective for a number of days in ordinary water. Numerous cases of extensive typhoid infection of the inhabitants of cities have occurred where the origin of the disease was clearly traced to the contamination of the water supply which came from a river where cases of typhoid fever had occurred in a settlement situated on this river at some distance above the station for taking out water to supply the city reservoir and a portion of the discharges from these had, during rains or otherwise, got into the river.

Such an infection has lately appeared in a large New England city and precisely this might occur from the proposed use of water from the Onondaga Creek in case of an outbreak of such an infective disease as typhoid fever, for instance, at and above

Cardiff. This water seems to present more chance of dangerous contamination of this sort than any of the others available. The fact that the number of bacteria found present was in all samples greater below than above the village of Cardiff would cause one to suspect a possible source of contamination from the numerous habitations in the region.

Although a large number of living bacteria need not in itself give sufficient ground for pronouncing a water objectionable, still, the fewer bacteria present, the nearer is the water to the ideal of excellence. Thus any hygienist would praise the water of Highland Lake (on the Hudson), which is fed by springs, has no streams flowing into it and no habitations near it; while the water of Poughkeepsie must be much less fit to be consumed in an unboiled state, coming as it does from the Hudson River which receives in its course the filth of very many habitations and industries. The pure mountain lake showed only 18 bacteria as the highest number found on three plates against 11,000 as the lowest number on three plates of the unfiltered river-water. River-water almost always shows a larger number of bacteria than lake or spring water, and I ought to state that the figures given above for Berlin are after its superior method of sand filtration had purified the original water which, when it comes from the River Spree, shows a larger number of living bacteria than the Hudson. Compared with the Hudson River water, that of Onondaga Creek is decidedly superior; compared with the Skaneateles Lake water, that from Onondaga Creek is decidedly inferior. Near Poughkeepsie there is no suitable lake or other source available. Near Syracuse there is an excellent supply to be had from Skaneateles Lake.

The samples of water from Onondaga Creek and the Syracuse Hydrant show so many bacteria and so many varieties that I consider them as deserving hygienically a rather low rank as drinking waters.

It should be mentioned that it had been raining the day before my examination of December 6. The snow had been melting for some days before my examination on December 30 of the water from Cardiff and higher up the Onondaga Creek, and was still

melting rapidly. The ground was so soaked with moisture that from it and from the patches of melting snow numerous rivulets were running over the alluvial fields down to the turbid and swollen stream, and in and beside the roads. Had it been colder and drier, the number of bacteria in the water would probably have been less.

I did not detect harmful varieties in any of the samples excepting that, from the water of Lake Oneida, I have detected and cultivated a bacillus which appears identical with one that is characteristic of, and constantly found in, human excrement (*Bacterium Coli Commune*). This is so unusual in water considered drinkable that I have conferred with and shown my cultures to other bacteriologists who agree with me concerning the identity of this species. I therefore consider the water of Lake Oneida as of somewhat doubtful quality from possibility of contamination ; yet the cause of this may have been a temporary one, in which case, later examinations would fail to detect the presence of the variety mentioned.

Among those present in my first sample from Lake Oneida I found a variety which is new to me and is not known to the bacteriologists to whom I have shown it, nor do I find it described in any of the literature of this subject, and therefore cannot be classified as harmful, and so far as my own experiments with it have determined its character it is harmless. It is a medium-sized, mobile bacillus, distinctly a deep green on the original plates, slowly liquifying ten-per-cent. gelatine, growing slowly on and in all culture media with a bluish and greenish color marked throughout, except that it is not so on all agar-cultures. On potato-culture, it grows very slowly and gradually the product becomes thick and dark green with a bluish element on dilution.

While the water of Lake Ontario, taken from a part several miles further away from Oswego, might present fewer bacteria and those of fewer kinds, the samples which I examined were such as to make me consider this water unsatisfactory.

The Gang Wells showed a larger number of bacteria than the accepted standard of such ground waters allows.

The water of Skaneatèles Lake, as found by me in these two examinations, appears unquestionably the best of all. It contains very many fewer bacteria than the water from any of the other sources, it has fewer varieties, and these bacteria are, so far as can be determined, of an entirely harmless character.

Of the three distinct varieties of water-bacteria found in the two examinations of this water, one variety occurred as a single colony only. This was the ordinary green fluorescent bacillus which does not fluidify gelatine and is found in the Croton water also. Apart from this singly-occurring one, the bacteria were of only two species: chiefly a non-fluidifying water-bacillus and also the white water-bacillus which is nearly always found in water and which liquefies gelatine rapidly. This water compares favorably with the best waters of which bacteriological analyses have been made.

Having to decide from these two bacteriological examinations I must consider Skaneateles Lake as by all means the best.

Next come the Gang Wells and Salmon River.

In the third rank come Oneida and Ontario Lakes.

Judging from the number and variety of bacteria present in it, the Onondaga Creek water, as it was found at the time when examined by me, deserves to stand last on the list.

CHARLES G. CURRIER, M. D.

The conclusions I draw from this report in connection with the chemical analysis, confirm those already reached from the latter alone.

The water of Lake Skaneateles is so far superior to all the other waters examined that it should be obtained for Syracuse if it can possibly be secured.

The Lake Ontario water is very suspicious. The Oneida Lake water is worse than suspicious. The water from the Gang Wells is suspicious, because while the actual number of organisms is not so great, it is very much greater than ought to be found in pure ground water, which is generally almost free from bacteria.

The Cardiff water is of doubtful quality from the bacteriological point of view, on account of the great number of organisms found in it. But it must be observed that chemically it shows well, and that the samples taken by Dr. Currier were procured at a time when the condition of the water was at its worst, and that none of the organisms appeared to be of a dangerous or suspicious class. It is probable that protection of the shores of the storage reservoir, the settling of the water in a large reservoir and proper filtration afterwards would make this water perfectly safe. From its chemical constituents and the nature of the water shed whence it flows, there is more likelihood of this water improving by storage and being free from the bad taste and odor which occurs in many stored waters, than could be expected from the Salmon River water.

The Salmon River water is passable, about the same when at its best as Croton and Cochituate water, but more likely than either of these waters, to be bad at times.

Ownership of Works.

Your instructions require me to present a statement as to the relative desirability of having your water-works owned and controlled by the City or by a private corporation.

Of the 50 largest cities of the United States, comprising all that have a population of over 50,000, only nine are supplied with water by private corporations. In the others the works are owned and operated by the cities.

Of the cities larger than Syracuse five only are supplied by private corporations, namely: San Francisco, New Orleans, Indianapolis, New Haven and Kansas City.

The statistics of water-works throughout the country seem to show that in the towns which have a public water supply the proportion of the population which uses the water is much greater than in towns which are supplied by water companies. Thus, in Cleveland, with a public water supply, there were in 1886 18,411 taps, while in New Orleans, with a slightly larger population, the water-works being owned by a private corporation, there were but 4,400 taps. In Allegheny there were 12,937 taps, while in Indianapolis, with about the same population, but a private water

supply there were 1,679 taps. In Worcester, Mass., with a public water supply there were 7,191 taps, while in Kansas City, with about the same population, but a private supply there were 6,080 taps. In Springfield, Mass., with a public water supply, there were 4,237 taps, and in Utica, N. Y., with a private supply, there were but 1,800 taps. In Trenton, N. J., with a public supply, there were 6,046 taps, while in Elizabeth, N. J., with about an equal population and a private water supply, there were only 3,000 taps. This proportion seems to run through the whole list of towns having a water supply.

The statistics of cost of private water companies are difficult to be obtained, and a comparison cannot well be made between public and private supplies in that respect except by examination of the water rate. In attempting to arrive at some conclusion as regards the relative cost of public and private supplies I have compared the water rates charged in several hundred towns.

The basis of assessment of water rates varies so greatly in different places that I found it necessary to assume certain conditions. In some towns the charges for water are based upon the number of persons living in the house, in others on the size of the house, either the number of square feet it occupies or the front width and the number of stories; in others again the basis of assessment is the value of the property, and in others again special fixtures are charged for separately.

To afford a basis for comparison I have assumed that a house valued at from $2,000 to $3,000 with a frontage of 20 to 25 feet, and occupying an area of 900 to 1,000 square feet and three stories high and having 10 rooms is occupied by 7 persons; having one bath-room, two water-closets, four wash-stands, three taps, or six extra faucets. Computing the annual rate to be paid by the occupant of such a building, I find that in 129 towns in which the water-works are owned by the public, the average rate per year is $18.20. In 123 towns in which the water-works are owned by companies, the average yearly water rent is $25. The accompanying diagrams (Plates 9 and 10) show graphically the water rate in each of the 252 towns referred to.

Supposing that there are 9,000 water takers in a town of 90,000 inhabitants, the difference to the consumers in the amount paid for water per annum by having a public water supply or a private water supply would be $61,200. In a town of that population there would be about 700 fire hydrants. A city ordinarily pays to the water company an annual rent for fire hydrants which averages as nearly as can be ascertained about $45 per hydrant per annum. This is paid out of taxation, so that in the town that we have assumed for comparison the taxpayers and the consumers together would pay the water company $256,500 per annum. The cost of maintenance for a gravity supply of this size is about $30,000 per year, and for a pumping supply about $75,000 per year, averaging $50,000 per annum for all towns. The taxpayers and consumers together would pay, therefore, for a public water supply approximately,

For water rent	$163,800
For maintenance	50,000
Total	$213,800

or about 17 per cent. less than would be paid to the company.

Part of the interest on the construction account must, however, be added in this case to the yearly charge, so that as far as cost to the people is concerned there is probably not much difference between the cost of water supplied by the city or by a private water company provided that an equal number of citizens use the water, but, as above stated, the evidence is very strong that where there is a supply by a private corporation the number of consumers is not nearly as great as in towns where the public owns and controls the water-works, and this from a sanitary point of view, or as regards protection against fire is a serious objection to having the water supply controlled by a private corporation.

The proportion of the total expenditure which is borne by the individual consumers, is much greater in the private water supply than in the public. The burden on the individual is greater and that on property less. This is unfair to the individual and tends to discourage the use of water. The existence of a good water supply is of very great value to property and the greater part of the burden ought to be borne by it and the individual charge made as small as possible.

The tendency of all private corporations is to build works as cheaply as possible, and to maintain them at as little cost as possible, and not to keep the plant up in an efficient manner further than is absolutely necessary to avoid forfeiture of their rights. On the other hand, when under public control the works are generally kept up in an efficient manner.

The general proportion of pipe in a well equipped water supply is one mile of pipe to every thousand inhabitants. In Syracuse the proportion is one mile to every 3,600 inhabitants. To keep up to the average of other cities, there ought to be at least 50 additional miles of pipes with the accompanying hydrants, laid at once.

The experience of most towns having a water supply is that the revenue from the consumers, even at the rates so much less than are charged by water companies, is sufficient to pay off the indebtedness incurred for the construction of the works and build all required extensions, and in many cases be a source of revenue to the city.

On the whole it appears as if it was better policy for a city to own its own water-works than to have them controlled by a private corporation.

As will be seen by the diagrams (Plates 9 and 10), the annual charge for water to an average family in Syracuse is above the average rate. There are about 3,000 consumers paying probably an average of $30 per year each and the hydrant charge paid by the city is $26,000 per annum, so that the amount paid by the people for water is not far from $116,000 per annum, besides the amount paid by manufacturers. With city ownership and the introduction of a supply of better water, the number of consumers would certainly be very largely increased and the rates could be diminished with the result of a large increase of revenue.

Availability and Value of the Existing Works.

In case of the introduction of a new supply the existing pipes and reservoirs of the water company would be available for the territory they now supply.

There is no way of ascertaining whether the present pipes are capable of sustaining a much-increased pressure. It is probable that the old cement-lined sheet-iron pipe could not stand much

increase of head and would have to be replaced from time to time as it failed.

The pumping plant of the water company could be made available for the low-service supply in case water is taken from Cardiff, and it could also be used with advantage for the high-service supply if the Salmon River water is introduced. It would not be needed for the present if water should be taken from Lake Skaneateles, but might be useful for a high-service supply in a few years.

I estimate that to build and equip new works of equal extent and capacity of supply would cost at the present time $850,000. Taking into account, however, deterioration of the plant, particularly the bad condition of the reservoirs and the older lines of pipe, the actual present value of the works is considerably less; but when, on the other hand, we consider the inconvenience which would be caused the public by a wholesale change at this time, and the value of the rights and franchises, the amount named would probably suffice to compensate the Water Company and the people for the transfer. I think that the proper compensation could only be fixed by arbitration.

Estimates of Cost.

The cost of introducing water from such of the sources as are not absolutely debarred from consideration for one reason or another, is estimated to be as follows:

SKANEATELES LAKE.

Length of lake	15 miles.
General width of lake	1 mile.
Area of lake	12¾ sq. miles.
Area of water-shed	57½ sq. miles.
Area of lake and water-shed	70¼ sq. miles.

High-water mark on stone (dated 1843) 463.4 feet above Syracuse level of Erie Canal.

SKANEATELES CREEK.

On Skaneateles Creek between the Lake and Seneca River are 25 dams and 41 mills with 68 wheels. Of these wheels 51 have an aggregate capacity of 2,439 horse-power, and of 17 wheels the capacity is unknown. On the creek are 6 unoccupied mill sites.

Conduit Line.

Distance to Knapp's Hill Reservoir	17 miles.
Length of line through limestone rock	6 miles.
Length of line through shale rock	½ mile.
Length of line in roads	0 miles.
Length of line from Knapp's Hill Reservoir to centre of city	2½ miles.
Elevation of Knapp's Hill Reservoir above the level of the Erie Canal	230 feet.

Estimate of Cost.

Gate house and inlet at Lake	$10,000
Conduit line of 30 inch cast-iron pipe from Lake to Reservoir on Knapp's Hill, 2½ miles west of Syracuse, 17 miles	737,141
Reservoir on Knapp's Hill, 230 feet above Canal, 70,000,000 gallons.	150,000
High service stand pipe	10,000
Water damages on Skaneateles Creek	472,000
Total cost	1,379,141
If it should be necessary to furnish compensation water to the State, this could be accomplished by building a Reservoir on Carpenter's Brook, covering 664 acres and holding 6,037 million gallons, and costing	732,952
Making the total cost	$2,112,093

CARDIFF SUPPLY.

Estimate of Cost.

Storage Reservoir at Cardiff, 42 feet deep at dam; capacity of reservoir, 4,340 million gallons. Land taken to be 1,000 feet wide around the outside of the Reservoir	$372,600
Conduit line of 36-inch pipe to pumping station, 8 miles @ $44,000	352,000
Pumping station, well and steam pumps of 10,000,000 gallons capacity daily	100,000
7,000 feet pumping main 20" @ $5	35,000
Reservoir on University Hill and stand pipe	160,000
Total cost	$1,019,600
Cost of pumping 200 feet. $6.000 per year for each million gallons per day; for 10 million gallons per day, $60,000, equivalent to interest @ 5 per cent. on	$1,200,000
Making total cost equivalent to	$2,219,600

If the city should purchase the plant of the Syracuse Water Company it would be available for this source of supply without erecting a new pumping station as above estimated.

SALMON RIVER.

Total area of water-shed.....70 sq. miles.
The Adams dam site is 3 miles above Redfield Square.
Total length of dam.....1,525 feet.
925 feet of dam is 42 feet in height above bottom of valley.
600 feet of dam is from 0 to 42 feet in height.
Elevation of Salmon River, at Adams dam, above Syracuse level of the Erie Canal.....558 feet.

STORAGE RESERVOIR.

Length of reservoir..... $1\frac{9}{10}$ miles.
Maximum width of reservoir..... $\frac{3}{5}$ mile.
Total area of reservoir.....370 acres.
Area to be cleared of timber.....220 acres.
Capacity of reservoir, 1,816,000,000 gallons.
Elevation of flow-line above Syracuse level of the Erie Canal.....590 feet.

The main road between Redfield Square and Osceola from dam site for the distance of one-third of a mile would be taken into reservoir. On this portion of the road there are three dwellings.

One-half mile above dam site the county line road crosses the reservoir in a diagonal direction. The length of road between flow-lines is two-thirds of a mile.

About 1½ miles from dam site is a good quarry,

On Salmon River between dam site and Lake Ontario are 9 dams, and 22 mills with 39 wheels having a capacity of 1,200 horse-power.

CONDUIT LINE.

Cast-iron pipe, 28 inches diameter from Adam's dam to Spicers and 42 inches diameter from Spicers to University Hill reservoir.

INTERMEDIATE RESERVOIR.

Reservoir at Spicers, 12 miles from Salmon River, holding 10,000,000 gallons, elevation.....317 feet.
Distance from dam to University Hill Reservoir.....$42\frac{72}{100}$ "
Length of line through rock..... $\frac{3}{5}$ "
" in roads..... 5 "
" under head of 600 feet from Storage Reservoir.... 15 "
" " 500 to 600 feet..... $3\frac{1}{2}$ "
" " 400 to 500 feet..... $5\frac{1}{4}$ "

By constructing the Spicer Reservoir the actual head on pipes is reduced 300 feet.

ESTIMATE OF COST.

Storage Reservoir at Adams's, between Redfield and Osceola, 32 feet at dam. Capacity of Reservoir, 1,816,000,000 gallons. Elevation above Canal at Syracuse, 590 feet.....	$487,945
Conduit line of 28-inch and 42-inch pipe, cast-iron pipe from storage reservoir to Reservoir on University hill, 42.72 miles.....	1,953,774
Reservoir at Spicers.....	50,000
Reservoir on University Hill, 250 feet above Canal, 70,000,000 gallons.....	150,000
Water damages on Salmon River.....	138,000
Total cost.....	$2,779,719

Oneida Lake.

Although the water from this Lake is considered unfit to use, an estimate has been made of the approximate cost of introducing water from this source.

Estimate of Cost.

Pumping Station	$150,000
Pipe Line, 85,000 feet	692,790
Reservoir in Syracuse	150,000
	$992,790
Annual cost of pumping ten million gallons daily, $75,000.	
Equivalent @ 5 per cent. to capital of	1,500,000
Making total cost equivalent to	$2,492,790

City Distribution.

There are 172 miles of streets in Syracuse.
There are now 33.17 miles of water mains in the city.
There are estimated to be needed for complete present distribution
50 miles of pipe, costing with hydrants complete $250,000

The entire cost of the introduction of a new supply of water, including the purchase of the Syracuse Water Company's plant and the extension of the distribution system so as to afford proper protection and convenience to the citizens, is estimated to be as follows, from these four sources of supply:

From Lake Skaneateles, including compensation to the State	$3,212,093
From Cardiff, including the cost of pumping, capitalized	3,219,600
From Salmon River	3,879,719
From Oneida Lake, including the cost of pumping, capitalized	3,692,790

I desire in conclusion to acknowledge the valuable and efficient service rendered in the examinations and the preparation of plans by Mr. W. R. Hill, and his assistants, Messrs. F. M. Wakefield, William Kelley, F. J. Schnauber and W. S. Farrington.

Respectfully submitted,

J. J. R. Croes, Civil Engineer.

TABLE VI.

Statement of Location, Length and Size of Water Mains in the City of Syracuse.

Name of Street.	Location.	Linear feet of Pipe.						
		24-in.	16-in.	12-in.	10-in.	8-in.	6-in.	4-in.
Adams	Warren to Montgomery							540
Ash	Salina to Townsend							400
Almond	Fayette to Genesee							450
Bank Alley	Washington to Fayette							420
Bear	Salina to Second North							2,430
Bradley	City Line to Putnam			1,335				
Burnet	James to Howard							2,480
Burnet	Lodi to Winton							2,540
Baldwin	West to Leaveworth Ave						1,135	
Burt	Selina to Mulberry			675				
Butternut	Salina to Lodi							1,537
Cedar	Lemon, west, to hydrant							150
Clinton	Onondaga to water							2,505
Cortland Ave.	Water Works to Salina	5,490						
Center.	Salina to Park							920
Church	Salina to Oswego Canal						370	
Crouse Ave	Genesee to Water							1,530
Crouse Ave	Genesee to Adams						1,535	
Catharine	Water to Lodi			3,810				
Castle	Mulberry to Salina						530	
Delaware	Onondaga to Geddes				2,585			
Division	Salina to Townsend							380
Elbridge	Oswego to Slocum Ave						725	
Exchange	Salina to Park							475
Franklin,	Church to Genesee						165	
Franklin	Fayette to Walton						260	
Franklin	Walton to Jefferson						170	
Franklin	Olive to Noxon							530
Franklin	Mechanic to Genesee							160
East Fayette.	Salina to Chestnut							4,205
West Fayette.	Salina to center of block, between Oswego and Tioga						3,685	
West Fayette.	Geddes to rolling mill							
Fulton	Salina to Spencer lot							1,240
Genesee	Montgomery to Salina					950		
Genesee	Montgomery to Beach						5,995	
West Genesee	Clinton to Plum							1,950
West Genesee	Plum to Geddes						2,720	
Gifford	Geddes to West							3,595
Grape	Jefferson to Harrison							995
Geddes	Putnam to Shonnard					1,400		
Geddes	Shonnard to Fayette				1,800			
Geddes	Fayette to Genesee					2,840		
Green	Catharine to Lodi							1,200
Hawley	Lodi to William						430	
Harrison	Salina to Mulberry							1,255
Howard	Burnet to Gertrude							395
Holland	Slocum Avenue to Delaware						2,120	
Irving	Genesee to Washington							885
Irving	Genesee to Harrison						1,030	
Jefferson	Salina to Lemon							3,285
Jefferson	Clinton Ave. to D. L. & W. depot							425
James	Salina to Warren							385
James	Pearl to Lock							435
James	Lock to east line of D. Gotts'						5,085	
Genesee	Geddes to Liberty						950	
Baldwin	Leavenworth Avenue to Van Rensselaer						800	
Liberty	Genesee to Park Avenue							620
Lodi	Butternut to Division			1,115				
Laurel	Fulton to Marsh							500
	Amounts carried forward	5,490		6,935	4,385	5,190	27,705	38,877

WATER MAINS—*Continued.*

Name of Street.	Location.	Linear feet of Pipe						
		24-in.	16 in.	12-in.	10-in.	8-in.	6-in.	4-in.
	Amounts brought forward....	5,490	.....	6,935	4,385	5,190	27,705	38,877
Lemon	Jefferson to Cedar..	.....	.. ..	.....	... ..	.....	... ..	285
Lock	Willow to James...	.....	.....	.....	.....	.....	345	.....
Lock	Erie Canal to James	.....	.. ...	.....	.. ...	635	... ..	.....
Lock	Salina to Isabella...	.....	.....	.....	.....	.....	.....	2,200
Lodi	Green to William.....	.....	.....	.....	.....	... ..	66c	... ..
Madison.. ...	Warren to Montgomery.... ..	.....	.....	.. ...	.....	.....	.....	530
Marcellus ...	West to Wyoming	.....	.....	.. ...	... ...	... .	450	.....
Montgomery..	Adams to Onondaga...	...	.....	.....	.. ..	... ..	.....	1,555
Montgomery..	Onondaga to Water.....	1,415	.....	..	.....	.. ..	.....	... ..
Mulberry.....	Burt to Erie Canal..... ..	.....	.....	.....	.....	4,555	.....	.....
Mulberry. ..	Burt to Castle..	.....	.....	.....	.. ...	1,745	.....	... ..
Mechanic	Franklin to Wallace.....	... .	.....	.....	.....	.....	.....	525
McBride	Butternut to Division.....	... ..	....	.....	.....	.....	... ..	1,055
McBride	James to Burnet	.....	....	.....	... ..	... ..	.....	830
Niagara.....	Fayette to Otisco	.....	.....	.....	.....	.....	730	.....
Noxon	Clinton to Wallace...	.....	... ..	.....	.....	.....	.....	715
Onondaga....	Pump House to Salina...	.....	.. ...	7,450	.....	.....	.....	.....
Otisco	Niagara to near Seneca.....	.....	.....	.....	.....	.....	.....	.....
Pond.....	Townsend to Alvord.	.....	.....	.....	.....	. . ..	1,390	.....
Putnam	Bradley to Geddes...	.....	.....	465	.....	.....	.. ..	500
Slocum Ave..	Elbridge to West Onondaga..	.....	... ..	.....	.....	... ..	.. ..	.....
South Onondaga.... ...	West Onondaga to Tallman..	... ..	. ..	. ...	.....	.....	700	.. ..
Seymour... .	Onondaga to Oswego.....	.....	.....	. ....	.	.....	1,135	... ..
Salina	Cortland Avenue to Warren..	1,270	.....	. ..	..	.....	2,485	.....
Salina.... ...	Burt to Castle.	.. ..	.....	.....	.....	....	. ..	.....
Salina...	Warren to Onondaga.....	... ..	....	.....	.. ...	1,085	1,805	.... .
Salina.....	Onondaga to Church.....	.....	.....	2,925	... ...	... ..	.....	.....
Salina...	Church to North Union Place	. ..	... ..	.....	..	5,046	.....	.. ..
Salina	North Union Place to Exchange.....	... .	.....	.....	.....	.....	3,361	.....
Sand	Genesee to Belden Avenue...	.....	.....	... ..	.....	.... .	.. ..	425
Spruce	Genesee south to school house.	.....	... ..	... ..	.....	... ...	.....	500
Townsend ...	Division to Isabella.....	.....	.....	.....	.....	.....	1,030	... ..
Turtle.... ...	Salina to Carbon.....	... ..	... ..	... .	... ..	.. ..	.....	988
Univers.tyAv.	Genesee to Adams	... ..	.....	.....	.....	1,545	.....	.....
Union	Butternut to Willow...	.....	.....	.....	.....	... ..	.....	1,770
Walton	Clinton to hydrant.....	.....	.....	.....	.....	.....	.....	33
Wallace.....	Mechanic to Noxon	.....	... ..	.....	... ..	.....	.....	660
Warren	Salina to Onondaga	1,450	... ..	.....	... ..	.....	.....	.....
Warren	Genesee to Washington....	.....	.. ...	.....	.....	.....	200	.....
Warren	Washington south to middle of block	... ..	.....	..	.....	.....	175	.....
Warren	Fayette to Onondaga.....	.....	.....	.....	.....	.....	.....	1,160
Washington..	Salina to Franklin	.....	.....	.. ..	.....	.....	.....	895
Washington..	Genesee to Beach	.....	.....	.....	.....	... ..	.....	5,795
Water	West to Franklin..... ..	.. ..	.....	.....	.....	.....	.....	1,000
Water	Salina to Montgomery.... .	.....	.....	... ..	... ..	... ..	.....	790
Water	Montgomery to Almond.....	.....	1,015	... ..	.....	.....	... ..	.....
Willow.....	Oswego Canal to Lock.....	... ..	.....	.. ..	.....	.....	435	.....
Willow..	Catharine to Lodi	... ..	.....	.....	.....	... ..	.....	720
Willow.....	Lock to east of Union	.....	.....	.....	.....	.....	... ..	500
Wolf	Salina to Carbon	.....	.....	.....	.....	... ..	950	... ...
Wolf	Carbon to Sixth North	.....	.....	.....	.....	.....	... ..	3,480
Wolf..... ..	Salina to Clarks' Mills...	.....	.....	.....	... ..	.....	.....	640
Wyoming	Fayette to Otisco.	... .	..	.....	... ..	... ..	.....	735
West.....	Onondaga to Fayette.....	.....	.....	.....	.....	.....	2,975	... ..
West.... .. .	Fayette to Erie Canal.....	.....	.....	.....	... ..	... ..	.....	590
West	Erie Canal to West Geneva...	.....	.....	.....	.....	.....	.....	1,030
William.....	Lodi to Hawley	... ..	.....	.....	.....	...	315	.....
Water	Salina to Franklin.....	... ..	.....	.....	.....	... .	875	.....
Almond.....	Cedar to Harrison.....	.....	.....	... ..	.....	... ..	710	.....
Genesee.....	Beech to Cherry.....	.....	.....	... ..	.....	.. ..	... ..	1,125
Hawley	Catharine to Howard.....	.....	.....	.....	... ..	... ..	785	.....
Johnson... .	Rust to Taliman..... ..	.....	.....	.....	.. ..	... .	1,090	.....
	Amounts carried forward....	9,625	1,915	17,775	4,385	19,801	50,521	69,908

WATER MAINS—*Continued.*

Name of Street.	Location.	Linear feet of pipe.						
		24-in.	16-in.	12-in.	10-in.	8-in.	6-in.	4-in.
	Amounts brought forward ..	9,625	1,915	17,775	4,385	19,801	50,521	69,008
Rust	Onondaga to Johnson						325	
Tallman	South Avenue to Hovey						820	
Leavenworth Avenue	Genesee to Whitney Wagon Works							855
Tracy	West to Pium							395
Wayne	Lodi to Howard							500
Townsend	James to Butternut						2,120	
Pine	Genesee to Washington							860
Furnace	Nelson to Hamilton Ave			2,935				
Fayette	Geddes to Nelson					1,815		
Center	Salina to Lodi							470
Court	Salina to Park St							474
Court	Salina to Lodi							470
Lodi	Hawley to Burnet							685
Canal	Lock to west of hydrant							290
Matty Ave	Park Ave. to Wilkinson							430
Oswego	Seymour to Elbridge						680	
G fford	West to Onondaga Creek						1,030	
West Fayette	Geddes to Oswego						1,485	
Franklin	Fayette to Railroad							335
Adams	Salina to Oneida							690
Almond	Cedar to Jefferson						285	
Cedar	Grape to Almond							925
Onondaga	Montgomery to Warren	585						
Delaware	Geddes to Idiot Asylum			1,270				
Roberts Ave	Bradley to Crossett			2,015				
	Total in feet	10,210	1,915	23,295	4,385	21,616	57,266	77,287
	Total in miles	1.93	0.36	4.41	0.83	4.09	10.84	14.64

LOCATION OF HYDRANTS IN THE CITY OF SYRACUSE.

First Ward.

1 Court and Park, N. W.
2 Turtle and Salina, S. W.
3 Turtle and Park, N. W.
4 Turtle and Carbon, N. E.
5 Bear and Salina, N. W.
6 Bear and Park, S. E.
7 Bear and Carbon, N. W.
8 Bear and Spring, N. W.
9 Bear and First, North, N. E.
10 Bear and Second, North, N. W.
11 Center and Salina, S. W.
12 Washington Park, S. W.
13 Center and Park, N. E.
14 Wolf and Salina, S. E.
15 Between Salina and Park, W. S.
16 Wolf and Park, N. W.
17 Wolf and Carbon, N. W.
18 Wolf and Spring, N. W.
19 Wolf and First, North, S. W.
20 Exchange and Salina, S. E.
21 Exchange and Park, S. W.
22 Court and Lodi, N. E.
23 Wolf and Second, North, N. E.
24 Wolf and Fifth, North, S. W.

Second Ward.

1 Court and Salina, S. W.
2 Salina and Kirkpatrick, S. E.
3 Butternut and Salina, N. W.
18 Division, between Salina and Townsend.
19 Division and McBride, S. E.

4 Butternut and Union, N. E.
5 Butternut and Townsend, N. E.
6 Butternut and McBride, N. E.
7 Butternut and Lodi, N. W.
8 Salina and Union, at Junction.
9 Ash and Lock, S. E.
10 Ash and Salina, S. W.
11 Ash and Townsend, N. E.
12 Ash and McBride, S. E.
13 Ash and Lodi, S. W.
14 West side of Lodi, facing John.
15 West side of Salina, between Ash and Division.
16 Division and Lock, S. E.
17 Division and Salina, N. E.
20 Division and Lodi, S. E.
21 West side of Salina, between Division and Catawba.
22 Catawba and Lock, S. E.
23 Catawba and Salina, N. W.
24 Catawba and Townsend, S. W.
25 West side of Salina, between Catawba and Isabella.
26 Isabella and Lock, S. E.
27 Isabella and Salina, N. W.
28 Lodi and Salina, at Junction.
29 Union Park and Salina, S. E.
30 Pond and Lodi, N. E.
31 Pond and Alvord, N. W.

THIRD WARD.

1 James and Warren, N. W.
2 James and Salina, N. E.
3 Clinton and Noxon, S. W.
4 Fulton, opposite Spencer House.
5 Church and Warren, S. W.
6 Church and Salina, N. W.
7 Church and Franklin, N. E.
8 Church and Genesee, at Junction.
9 West side of Salina, midway between Church and Genesee.
10 Genesee and Clinton, N. E.
11 Genesee and Franklin, N. E.
12 Genesee and West, S. E.
13 Genesee and Plum, S. W.
14 North side of Genesee, midway between Plum and State Race.
15 Genesee and Leavenworth Ave., S. W.
16 Genesee and Van Rensselaer, S. W.
17 South side of Genesee, midway between Van Rensselaer and Geddes.
18 Genesee and Geddes, S. E.
19 Noxon and Salina, N. W,
20 Noxon and Franklin, N. E.
22 Belden Ave. and Fulton, N. W.
23 Belden Ave. and Franklin, S. W.
24 North side of Mechanic, opposite Gas House.
25 Baldwin and West, S. W.
26 East side of North West, near Tracy.
27 Alley, near Greenway's Brewery.
28 Geddes and Park Ave., N. E.
29 Geddes and Wilkinson, N. E.
30 Geddes and Richmond, N. E.
31 Baldwin and Plum, S. E.
32 Park Ave. and Plum, S. W.
33 Park Ave. and Barker Ave, S. E.
34 Park Ave. and Leavenworth Ave., S. W.
35 Park Ave, and Matty Ave., S. W.
36 Park Ave. and Van Rensselaer.
37 Matty Ave. and Wilkinson, N. E.
38 Leavenworth Ave. and Belden Ave., S. W.
39 Leavenworth Ave. and Clark, N. W.
40 Leavenworth Ave., opposite Whitney Wagon Works.
41 Plum and Tracy, N. E.

21 West side of Wallace, near Noxon.
42 Belden Ave. and Sand, S. E.
43 West Genesee and Liberty, S. E.

FOURTH WARD.

1 Canal and Lock, N. E.
2 Canal and Catharine, N. E.
3 North side of Burnet, midway between Townsend and Lock.
4 Burnet and Townsend, S. E.
5 Salina and Lock, N. E.
6 Union and Hickory, N. E.
7 Union and Bridge, N. W.
8 Union and Laurel, S. E.
9 Lodi and Gertrude, N. E.
10 East Side of Lodi, junction of Lodi and William.
11 William and Hawley, N. W.
12 William and Canal, S. W.
13 Burnet and McBride, N. E.
14 Burnet and Catharine, S. W.
15 Burnet and Catharine, N. E.
16 Burnet and Howard, N. W.
17 South side of James, between Pearl and Oswego Canal.
18 James and Lock, N. W.
19 James and Lock, S. E.
20 South side of James, midway between Lock and Townsend.
21 James and Townsend, N. E.
22 James and McBride, S. E.
23 James and Catharine, N. W.
24 James and Catharine, S. E.
25 South side of James, midway between Catharine and Lodi.
26 James and Lodi, N. W.
27 Hawley and McBride, S. E
28 Hawley and Catharine, N. E.
29 Gertrude and Howard, N. E.
30 Green and Catharine, N. E.
31 Green and Howard, N. W.
32 Green and Lodi, S. W.
33 Wayne and Catharine, N. E.
34 Willow and Pearl, S. W.
35 Willow and Lock, N. E.
36 Willow and Union, N. E.
37 Willow and Catharine, N. E.
38 Lodi and Burnet, S. E.
39 Lodi and Oak, N. E.
40 Lodi and Finegan Ave, S. E.
41 Lodi and Hawley, N. W.
42 South side of Willow, midway between Catharine and Lodi.
43 Willow and Lodi, N. W.
44 Hickory and Catharine, N. E.
45 West side of Catharine, midway between Hickory and Laurel.
46 Salina and Pearl, N. E.
47 Burnet and Beach, S. W.
48 Burnet and Elm, S. W.
49 Burnet and Vine, S. E.
50 Burnet and Winton, S. W.
51 Townsend and Willow, S. W.
52 Townsend and Hickory, S. W.
53 Townsend and Union Av., N.W.
54 Townsend and Laurel, S. W.
55 Canal and Pearl, S. E.
56 Howard and Wayne, S. W.
57 Lodi and Wayne, S. W.
58 Catharine and Laurel, S. W.
59 North side of Hawley, between Catharine and Howard.
60 Townsend and Brown, N. W.
61 James and Highland, N. W.

FIFTH WARD.

1 South side of West Water, opposite Barker's Mill.
37 North side of Onondaga, near Delaware.

2 Fayette and West, S. E.
3 Fayette and Wyoming, S. W.
4 Fayette and Niagara, S. W.
5 Fayette and Tioga, S. W.
6 Fayette and Oswego, S. W.
7 Fayette and Ontario, S. W.
8 Marcellus and West, S. W.
9 Marcellus and Wyoming, S. E.
10 Marcellus and Niagara, N. E.
11 East side of Wyoming, in front of Engine House No. 3.
12 Otisco and West, N. W.
13 Otisco and Wyoming, S. E.
14 Otisco and Niagara, N. E.
15 Otisco and Tioga, S. E.
16 Otisco and Oswego, S. E.
17 South side of Otisco, between Oswego and Seneca.
18 Tully and West, S. W.
19 Fabius and West, S. W.
20 Gifford and West, S. E.
21 Gifford and Niagara, S. E.
22 Gifford and Oswego, N. W.
23 North side of Gifford, between Oswego and Geddes.
24 South side of Gifford, between Oswego and Geddes.
25 Gifford and Geddes, S. E.
26 Seymour and Onondaga, S. W.
27 Seymour and West, S. E.
28 Seymour and Niagara, S. E.
29 Seymour and Oswego, S. E.
30 Shonnard and West, N. W.
31 Gifford and Granger, N. W.
32 North side of Gifford, midway between Granger and Creek Bridge.
33 Shonnard and Geddes, N. E.
34 North side of Onondaga, near Rust.
35 South side of Onondaga, near Rust.
36 North side of Onondaga, midway between Rust and Delaware.
38 South side of Onondaga, corner of Delaware.
39 Geddes and Delaware, N. E.
40 Corner of Fitch and Geddes.
41 South side of Delaware, near Kellogg.
42 South side of Delaware, near Grace.
43 South side of Delaware, near Salina.
44 South side of Delaware, midway between Sabine and Geddes.
45 Putnam and Bradley, S. W.
46 Putnam and Geddes, S. W.
47 Geddes and Fayette, N. E.
48 Oswego and Shonnard, S. E.
49 Oswego and Elbridge, S. E.
50 Elbridge and Kellogg, S. E.
51 Kellogg and Slocum Avenue, S. E.
52 Onondaga and Slocum Avenue, N. E.
53 East side of South Avenue, midway between Onondaga and White.
54 South Avenue and Tallman, N. E.
55 South side of Holland, between Slocum Avenue and Oswego.
56 South side of Holland, opposite Oswego.
57 South side of Holland, between Oswego and Ontario.
58 South side of Holland, opposite Ontario.
59 South side of Holland, between Ontario and Delaware.
60 Rust and West Onondaga, S. E.
61 Rust and Johnson, S. E.
62 Johnson, midway between Rust and Tallman.
63 Johnson and Tallman, N. E.
64 Tallman and Hovey, S. E

Sixth Ward.

1 Franklin and Water, S. W.
2 Franklin and Washington, S. E.
3 Franklin and Fayette, N. E.
4 Franklin and Walton, S. W.
5 Clinton and Water, S. W.
6 Jefferson Street, near S. & B. Railroad Depot.
7 East side of Clinton, midway between Water and Washington.
8 Clinton and Washington, S. E.
9 Clinton and Fayette, N. W.
10 Clinton and Fayette, S. E.
11 Clinton and Walton, S. W.
12 Clinton and Jefferson, S. E.
13 East side of Clinton, between Jefferson and Onondaga.
14 South side of Water, between Franklin and Onondaga Creek.
15 South side of Water, between Clinton and Salina.
16 East side of Salina, between Water and Washington.
17 Salina and Washington, N. W.
18 Salina and Washington, S. E.
19 Salina and Fayette, N. W.
20 Salina and Fayette, S. E.
21 Salina and Jefferson, N. W.
22 West side of Salina, between Jefferson and Onondaga.
23 East side of Salina, between Jefferson and Onondaga.
24 Salina and Harrison, N. E.
25 Harrison and Montgomery, S.W.
26 Salina and Burt, N. E.
27 Salina and Taylor, N. E.
28 Salina and Jackson, N. E
29 East side of Salina, near junction of Warren.
30 West side of Salina, near junction of Warren.
31 Salina and Adams, N. W.
32 Warren and Adams, N. E,
33 Warren and Harrison, S. W.
34 Warren and Onondaga, S. W.
35 Warren and Jefferson, S. W.
36 West side of Warren, midway between Jefferson and Fayette.
37 Warren and Fayette, S. E.
38 East side of Warren, between Fayette and Washington.
39 Warren and Washington, N. W.
40 North side of Madison, midway between Warren and Montgomery.
41 Jefferson and Jefferson Alley, N.W.
42 Fayette and Jefferson Alley, N. E.
43 Montgomery and Madison, N.W.
44 Montgomery and Jefferson,. S. E.
45 Montgomery and Fayette, N.W.
46 Montgomery and Genesee, N. W.
47 West side of Montgomery, between Genesee and Water.
48 South side of Genesee, midway between Salina and Warren.
49 South side of Water, midway between Warren and Montgomery.
50 South side of Water, midway between Clinton and Franklin.
51 Adams and Baker, S. E.
52 Adams and Oneida, S. E.
53 Warren and Harrison, N. E.
54 Franklin and Jefferson Place, N.W.
55 Madison and Warren, N. E.
56 South side of Onondaga, opposite Monttgomery.
57 East side of Franklin, between Fayette and Washington.

Seventh Ward.

1 Montgomery and Genesee, S. E.
2 Montgomery and Fayette, N. E.
28 Grape and Genesee, S. W.
29 Grape and Jefferson, N. W.

3 Montgomery and Jefferson, N. E.
4 Montgomery and Adams, N. E.
5 Mulberry and Water, S. W.
6 Mulberry and Washington, N.W.
7 Mulberry and Washington, S. E.
8 Mulberry and Genesee, N. W.
9 Mulberry and Onondaga, N. W.
10 Mulberry and Jefferson, S. W.
11 Mulberry and Cedar, S. E.
12 Mulberry and Madison, S. E.
13 Mulberry and Harrison, N. E.
14 Mulberry and Harrison, S. W.
15 Mulberry and Adams, S. E.
16 East side of Mulberry, midway between Adams and Jackson.
17 Mulberry and Jackson, N. E.
18 Mulberry and Taylor, N. E.
19 Mulberry and Burt, N. E.
20 Mulberry and Van Buren, S. E.
21 East side of Mulberry, midway between Van Buren and Croton.
22 Mulberry and Croton, S. E.
23 East side of Mulberry, midway between Croton and Castle.
24 Mulberry and Castle, N. E.
25 Grape and Water, S. W.
26 Grape and Washington, S. W.
27 Grape and Fayette, S. E.
30 Grape and Cedar, S. W.
31 Grape and Madison, S. E.
32 Grape and Harrison, S. W.
33 Orange and Water, S. W.
34 Orange and Washington, S. E.
35 Orange and Fayette, N. E.
36 Orange and Genesee, N. E.
37 Orange and Jefferson, S. W.
38 Almond and Water, N. W.
39 Almond and Jefferson, N. W.
40 Junction of Fayette and Genesee.
41 South side of Genesee, midway between Mulberry and Grape.
42 East side of South Salina, midway between Burt and Tallman.
43 East side of South Salina, opposite Tallman.
44 South Salina and Croton, S. E.
45 East side of South Salina, midway between Croton and Castle.
46 South Salina and Castle, N. E.
47 Cedar and Montgomery, N. E.
48 Cedar and Grape, N. W.
49 Cedar and Orange, N. W.
50 Cedar and Almond, N. W.
51 East side of Montgomery, between Fayette and Jefferson.

EIGHTH WARD.

1 North side of Genesee, midway between Almond and Lemon.
2 Genesee and Maple, N. W.
3 Genesee and Cherry, N. W.
4 North side of Fayette, between Lemon and Irving.
5 North side of Cedar, near Lemon.
6 Almond and Washington, S. E.
7 Almond and Fayette, S. E.
8 Almond and Genesee, N. E.
9 Almond and Madison, S. E.
10 Almond and Harrison, N. E.
24 Chestnut and Fayette, S. W.
25 Chestnut and Genesee, N. E.
26 University Ave. and Washington, S. E.
27 University Avenue and Genesee, S. E.
28 University Avenue and Madison, N. E.
29 University Avenue and Harrison, N. E.
30 University Avenue and Adams, N. E.

11 Lemon and Washington, N. E.
12 Lemon and Fayette, N. W.
13 Lemon and Quince, N. E.
14 Lemon and Genesee, N. E.
15 Lemon and Jefferson, S. W.
16 Irving and Washington, N. W.
17 Irving and Fayette, S. E.
18 Irving and Genesee, N. E.
19 Irving and Cedar, S. W.
20 Irving and Madison, N. E.
21 Irving and Harrison, S. E.
22 Chestnut and Water, S. E.
23 Chestnut and Washington, S. W.
31 Spruce and Washington, S. E.
32 Spruce and Genesee, N. E.
33 Pine and Washington, S. W.
34 Pine and Genesee, N. W.
35 Beach and Washington, S. W.
36 Beach and Genesee, N. W.
37 East side of Pine, opposite Gazelle.
38 Pine and Fayette, S. E.
39 Chestnut and Madison, S. E.
40 Chestnut and Harrison, S. E.
41 Chestnut and Adams, N. E.

NINTH WARD,

1 Geddes and Hemlock, N. W.
2 West side of Geddes, Straight Line Engine Works.
3 Fayette and Magnolia, S. W.
4 Fayette and Nelson, S. E.
5 North side of Furnace, between Nelson and Ulster.
6 Furnace and Ulster, S. W.
7 Furnace and Schuyler, N. E.
8 Furnace and Hamilton Avenue, S. E.
9 to 15 Idiot Asylum Grounds, 7.

REPORT ON METHODS OF ANALYSIS, BY PROF. H. B. CORNWALL.

J. JAMES R. CROES, C. E.,
New York.

DEAR SIR:—I herewith send you my final report on the waters from various sources received from you during this Fall, which you desired me to examine in connection with your investigation of a practicable supply for Syracuse, N. Y.

As learned from you, the samples have been drawn from the following sources:

No. 1.—Skaneateles Lake. Received with Nos. 2, 3 and 4.

No. 2.—Ground Water in the valley of Onondaga Creek, drawn from 30 feet below the surface. Taken Sept. 8th.

No. 3.—Hydrant of Syracuse Water Co. The supply comes from Onondaga Creek and is pumped into the Mains. Sample taken Sept. 10th.

No. 4.—Oneida Lake. Taken Sept. 10th.

No. 5.—Seneca River above Baldwinsville.

No. 6.—Onondaga Creek, at site of proposed dam at Cardiff. Taken Sept. 13th.

No. 7.—Otisco Lake, N. Y. Taken Sept. 13th.

No. 8.—Salmon River, at site of proposed storage reservoir. Taken Sept. 28th.

No. 9.—Same source as No. 2. Taken Oct. 23d.

No. 10.—Onondaga Creek, opposite to plateau in which the gang wells are bored.

No. 11.—Green Lake; one of the Tully Lakes.

No. 12.—Lake Ontario. Taken Nov. 28th.

I have examined the above samples with a view both to their sanitary fitness and their use for household and manufacturing purposes, including use in steam boilers.

Briefly stated, the methods of analysis have been as follows:

Free Ammonia is determined by boiling the water with a very small addition of carbonate of soda and determining, in a fixed portion of the distillate, the ammonia with Nessler's reagent.

Albuminoid Ammonia is determined by further boiling the same portion of water with addition of strongly alkaline solution of permanganate of potash and determining the ammonia in successive portions of the distillate.

Chlorine is determined by means of a standard solution of nitrate of silver, using chromate of potash as an indicator.

Nitrogen as nitrates (nitrites were not found to be present) is determined by Crum's method; liberation of nitrogen dioxide gas from the concentrated water by action of sulphuric acid over mercury, and calculation of the nitrogen from the volume of the gas.

Oxygen consumed (by oxidizable matter present) is determined by the Kubel-Tiemann method; boiling the water with a slight excess of very dilute solution of permanganate of potash (after acidifying the water with sulphuric acid) and determining the excess of permanganate by oxalic acid solution. This is the most thorough method of applying the permanganate test.

Total Solids are determined by evaporating 70 cubic centimetres of the water to dryness in a platinum dish and drying the residue at 110° Centigrade (230° Fahr.). Tests on Nos. 2 and 9 showed that identical results were obtained at 100° Cent. (212° Fahr.) and 135° Cent. (275° Fahr.).

Loss on Ignition.—This is determined by igniting the dry residue at the lowest possible temperature until the organic matter is consumed and then repeatedly evaporating small portions of water saturated with carbonic acid in the dish, to reproduce the carbonates decomposed by the ignition. Finally the residue is again dried at 110° Cent. and weighed.

Total Hardness is determined in 70 cubic cent. of the water by means of standard soap solution. In my report of results of analysis the hardness is expressed as equivalent to that which would be produced by an equal number of parts of carbonate of lime in 100,000 parts of otherwise pure water.

Temporary hardness is determined by boiling 100 cub. cent. of the water for half an hour, constantly replacing the loss by evaporation with recently boiled, distilled water, making up the volume to the original 100 cub. cent., filtering out the precip-

itated carbonates, determining the (permanent) hardness in the filtered water and deducting this from the total hardness.

Carbonate of lime is determined either by evaporating 100 cub. cent. of the water to dryness, dissolving out the salts of the alkalies (and most of the carbonate of magnesia) with hot, distilled water, and testing the alkalinity of the insoluble residue by means of decinormal sulphuric acid :

Or, by directly determining the alkalinity of the water (200 cub. cent. of it) by means of decinormal solutions of sulphuric acid and of potassa.

Both methods were tried on my samples, and the results agreed closely with one another, as well as with the indications by the temporary hardness test.

Interpretation of the analysis.—The grounds for such interpretation cannot be given in a short space, because so many facts must be taken into consideration at the same time.

The chief points, so far as our samples are concerned, may be briefly stated as follows :

Free ammonia, not exceeding 0.005 parts per 100,000, if accompanied by a nearly as small amount of *albuminoid ammonia* indicates the probable absence of any recent drainage (or sewage) contamination.

Albuminoid ammonia not exceeding 0.015 per 100,000, with little *free ammonia*, indicates absence of nitrogenous organic matter to any objectionable extent. The presence of any considerable amount of *free ammonia* with so much *albuminoid ammonia* would be a suspicious indication.

Chlorine, present chiefly as sodium chloride (common salt) when exceeding the quantity normal to the water of any district is a suspicious indication, pointing to some sort of drainage contamination. In the neighborhood of Syracuse, however, quantities as large as any of those in our samples might be expected to normally exist.

Nitrogen as nitrates in any considerable quantity, as from 0.5 per 100,000 upward, is ordinarily an indication of household or drainage contamination.

Oxygen Consumed.—This test is to be regarded rather as

supplementary to the *albuminoid ammonia* than as of great importance in itself, since even when in excess of the average quantity it scarcely indicates any dangerous impurity. At the same time, when a water shows a considerable excess in this respect, there is reason to examine the source carefully before adopting it as a water-supply, because, at the least, such a water might, by causing vegetable growths in reservoirs and mains, finally prove objectionable. *Oxygen consumed* is especially liable to be found large in river and lake waters.

Total solids.—When these exceed 50 or 55 per 100,000 they alone constitute an objection to a water supply, unless they can be readily reduced by some treatment of the water, such as a softening process. In our samples the total solids are almost wholly due to mineral salts and very largely to lime, with some magnesia salts.

Loss on ignition.—Formerly this was used as a rough indication of *organic matter*, but it has lost what little importance it possessed, since the introduction of the more accurate tests already described. Its results scarcely admit of interpretation in case of waters containing much mineral salts, because these undergo varying degrees of decomposition during the ignition. In case of some of our samples the loss is undoubtedly due chiefly to decomposition of the mineral matter, but the results have been tabulated for possible purposes of comparison.

Hardness.—A water not exceeding 18 to 20 per 100,000 in total hardness is still available for domestic purposes, although very badly adapted for laundry purposes, and apt to form troublesome deposits in boilers. The *temporary hardness* in our samples is due chiefly to carbonate of lime, held in solution by free carbonic acid. When the latter is expelled by boiling, the carbonate of lime for the most part separates as an insoluble precipitate. Since the hardness due to the dissolved carbonate of lime can be thus diminished by boiling, this hardness is called temporary hardness. The temporary hardness does not, however, represent the whole of the carbonate of lime originally present, because even after boiling, the water still retains some dissolved carbonate; sometimes about 3 parts 100,000 thus

remaining in solution. To a certain extent carbonate of magnesia also causes temporary hardness in our samples, but practically it may be regarded as due simply to carbonate of lime, of which in one of the worst samples there was found to be five times as much as there was of carbonate of magnesia.

The difference between the total and temporary hardness is called *permanent hardness.* Aside from the small amount of carbonate of lime (and magnesia) the soluble salts of these two, especially in our samples the sulphates, are the cause of the permanent hardness; not being thrown down as insoluble salts in boiling, provided the evaporated water is replaced by distilled water during the operation. If this is not done the concentration of the water due to evaporation, as in steam boilers, causes separation especially of the sulphate of lime also, and this is peculiarly liable to form a hard, troublesome boiler scale.

The temporary hardness due to carbonate of lime in solution can be almost entirely removed by a proper addition of lime water or of milk of lime, which combines with the free carbonic acid. It can also to a great extent be removed by a preliminary heating of the water and both of these methods, singly and combined, are used for the purpose; the former on a very large scale, the latter (requiring some cheap source of heat) necessarily is confined to establishments where this is available.

Chemical agents also are used to diminish the permanent hardness. They will be mentioned later.

Since a certain amount of soap must be first used up, in decomposing the salts causing hardness, before the water will lather well and be at all fit for washing, there is necessarily great economy of soap in using a softer water. For culinary purposes and for many technical uses, also, a very hard water is undesirable. Moreover, very hard waters are apt to interfere with the digestive functions.

Moderately hard waters, of 10 to 14 per 100,000 are frequently used, without much inconvenience, for all ordinary purposes with no preliminary purification; and even somewhat harder waters are so used when the permanent hardness is

not great. This is especially true when the amount of sulphate of lime is only trifling.

In applying the above principles to the results of analysis of a water we must remember that the chemical analysis is useful chiefly as a sort of first step. If a water is shown by it to be very pure, then unless the surroundings are such as evidently to be dangerous the water may be accepted. On the other hand, the analysis may appear to condemn a water that would be available. In my remarks on the results I have endeavored so far as I could to draw only the conclusions warranted by the analysis.

One of the most important questions connected with several of our samples is that of hardness, and especially of the proportions of carbonate and sulphate of lime to which the temporary and permanent hardness respectively are for the most part due. In two cases, determinations of the lime, sulphuric acid (more properly speaking sulphuric anhydride SO_3) and of the carbonate of lime were made by chemical analysis, as a check on the determinations of temporary hardness already made. The results agreed so well that the determinations of temporary hardness in the other samples may also be regarded as correct for all practical purposes.

In No. 2 there was found per 100,000 parts:

Lime (Ca O) 17.90
Sulphuric Anhydride (SO_3) 16.01
Carbonate of Lime (Ca CO_3) 16.75
Sulphate of Lime (Ca SO_4) 20.69

In No. 9 there was found:

The *total hardness* due to all of the lime, reckoned as Ca CO_3, would be 47.75 per 100,000.

Lime 26.74
Sulphuric Anhydride ... 28.76
Carbonate of Lime 20.75
Sulphate of Lime 36.72

Both of these samples were taken from the gang wells.

Qualitative tests showed a small amount of magnesia in both waters. The *sulphate of lime* is not actually determined by analysis, but calculated from the lime not combined as carbonate. In comparing the carbonate of lime with the temporary hardness it must be remembered that some carbonate of lime remains even in boiled water, as has already been stated.

It remains to consider the question of reducing the hardness of our samples. Although some do not need this, and although others would require only that the temporary hardness should be removed, yet in all cases the amounts of lime and of carbonate of soda (the best materials for these samples) have been calculated. At the same time it should be stated that as the waters would vary from time to time, requiring a careful adjustment of the chemical reagents, the figures here given can be taken only as a guide in considering the expense of the softening.

On the large scale, for supplying a town, the only practicable softening is with lime, known as Clark's process. There is not space here to go into details. The necessary amount of quick-lime is slaked with water, then stirred up to milk of lime and well mixed with the water to be softened. In twelve hours or so the carbonate of lime settles, leaving the water clear enough for drinking, and removing the temporary hardness; but not the permanent. The lime acts by combining with the free carbonic acid, which previously held the carbonate of lime in solution. It may be remarked that waters are generally much freed from organic impurity also, by this process of softening. On the small scale, for steam boilers and for manufacturing purposes, this process is very readily carried out, being much hastened by agitating the water mechanically, or by pumping in air.

To remove the permanent hardness the further use of carbonate of soda would be best. The lime and carbonate of soda are added one after the other, or both together—the process being hastened by warming or by agitation of the water. Although costing too much for use on the largest scale, this method is often very profitably employed in large establishments. The carbonate of soda throws down the lime as insoluble carbonate from the sulphate, nitrate and other soluble salts of lime. The magnesia is also in great part separated, so that very hard waters can be made quite soft by this means.

In the following table are given the quantities of quick-lime and *crystallized* carbonate of soda necessary for 100,000 gallons of each water; it being understood that the lime removes the temporary hardness only, and the carbonate of soda the residual permanent hardness.

To remove one part of temporary hardness requires 0.56 part of quick lime ; to remove one part of permanent hardness requires 2.86 parts of crystallized carbonate of soda. Taking the U. S. gallon at 58,318 grains, one part hardness per 100,000 corresponds to 0.58318 grains carbonate of lime per gallon of water, or to 58,318 grains per 100,000 gallons. Therefore, each part of temporary hardness will require 32,658 grains (or $4\frac{67}{100}$ pounds) of quick-lime, and each part of permanent hardness will require $23\frac{8}{10}$ pounds of carbonate of soda.

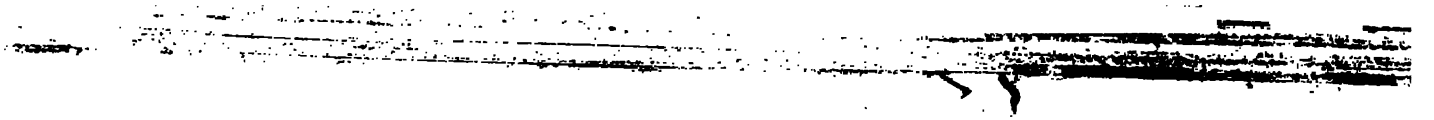
Sample.	Total Hardness.	Temp. Hardness.	Quick lime to remove temp. hard., per 100,000 gal.	Perm. Hardness.	Carbonate soda to remove perm. hardness, per 100,000 gal.	
No. 1.	9.3	6.4	29 lbs. 14 ozs.	2.9	69 lbs..... ...	Skaneateles Lake, Sept. 7.
No. 2.	32.	15.	70 lbs.	17.	404 lbs. 9 ozs..	Gang Wells, Sept. 8.
No. 3	33.7	14.7	68 lbs. 9 ozs.	19.	452 lbs. 3 ozs ..	City Hydrant, Sept. 10.
No. 4.	9.4	1.6	7 lbs. 7 ozs.	7.8	185 lbs. 9 ozs..	Oneida Lake, Sept. 10.
No. 5.	14.5	7.	32 lbs. 11 ozs.	7.5	178 lbs. 8 ozs..	Seneca River, Sept. 14.
No. 6.	18.1	12.5	58 lbs. 6 ozs.	5.6	133 lbs. 4 ozs...	Cardiff, Sept. 13.
No. 7.	9.6	4.8	22 lbs. 6 ozs.	4.8	114 lbs. 4 ozs...	Otisco Lake, Sept. 13.
No. 8.	4.3	.....	Not taken.	....	. ...	Salmon River, Sept. 28.
No. 9.	48.5	18.8	87 lbs. 13 ozs.	29.7	706 lbs. 12 ozs...	Gang Wells, Oct. 23.
No. 10.	24.3	16.6	77 lbs. 8 ozs.	7.7	183 lbs. 4 ozs...	Onondaga Creek, Oct. 23.
No. 11.	10.8	2.8	13 lbs. 1 oz	8.	190 lbs. 6 ozs ..	Green Lake, Oct. 29.
No. 12.	12.	4.9	22 lbs. 14 ozs.	7.1	169 lbs	Lake Ontario, Nov. 28.

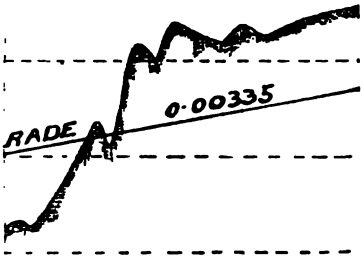
Poisonous Metals.—The waters were all free from any amount of lead, copper or iron that can be detected by the usual methods, viz., testing the water directly with ammonium sulphide.

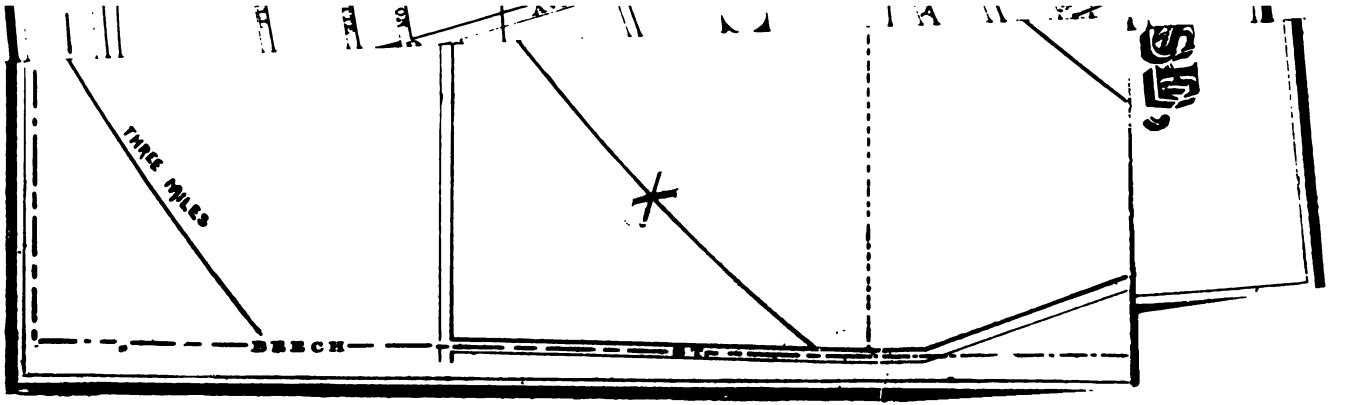
Very respectfully yours,

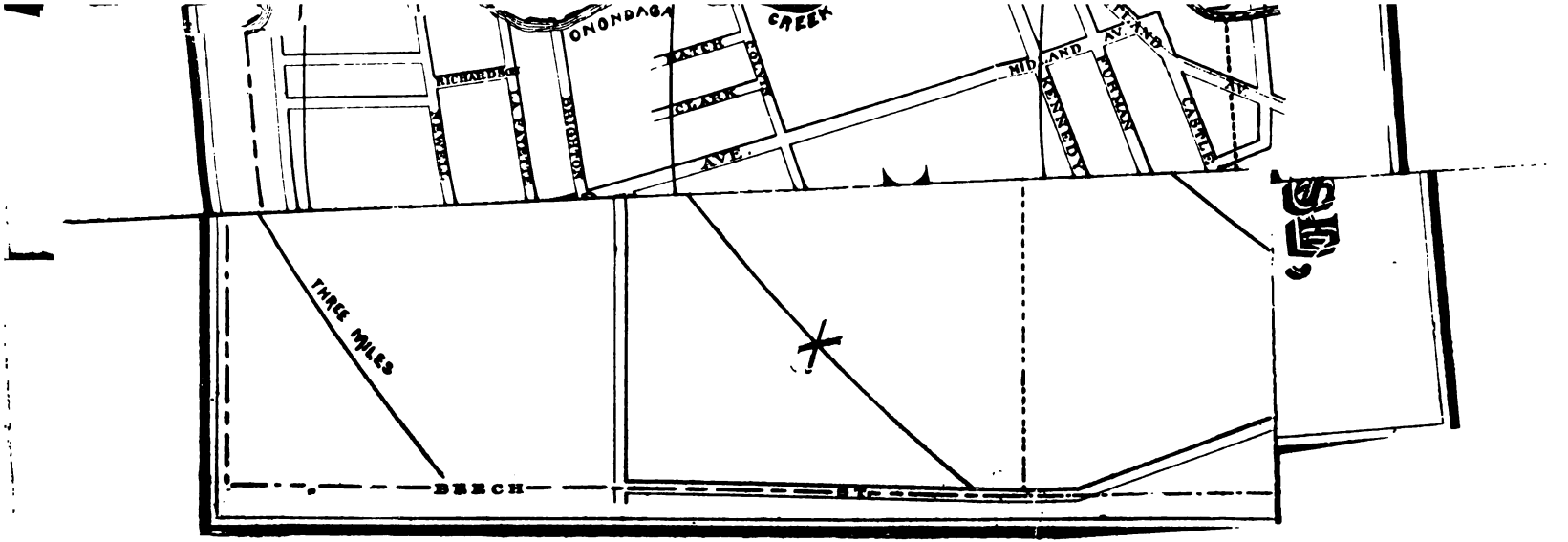
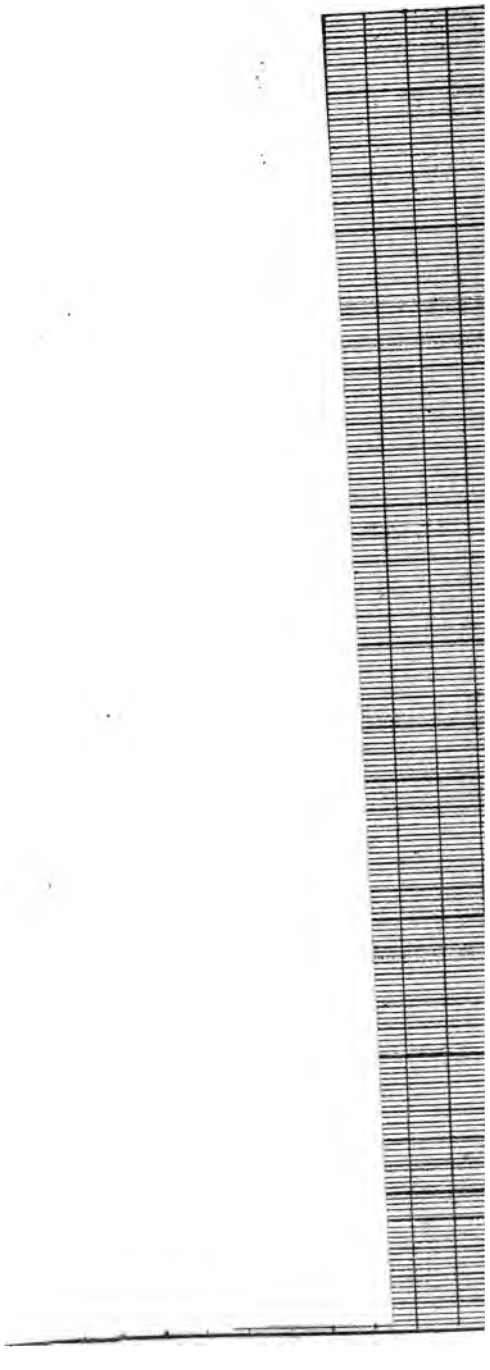
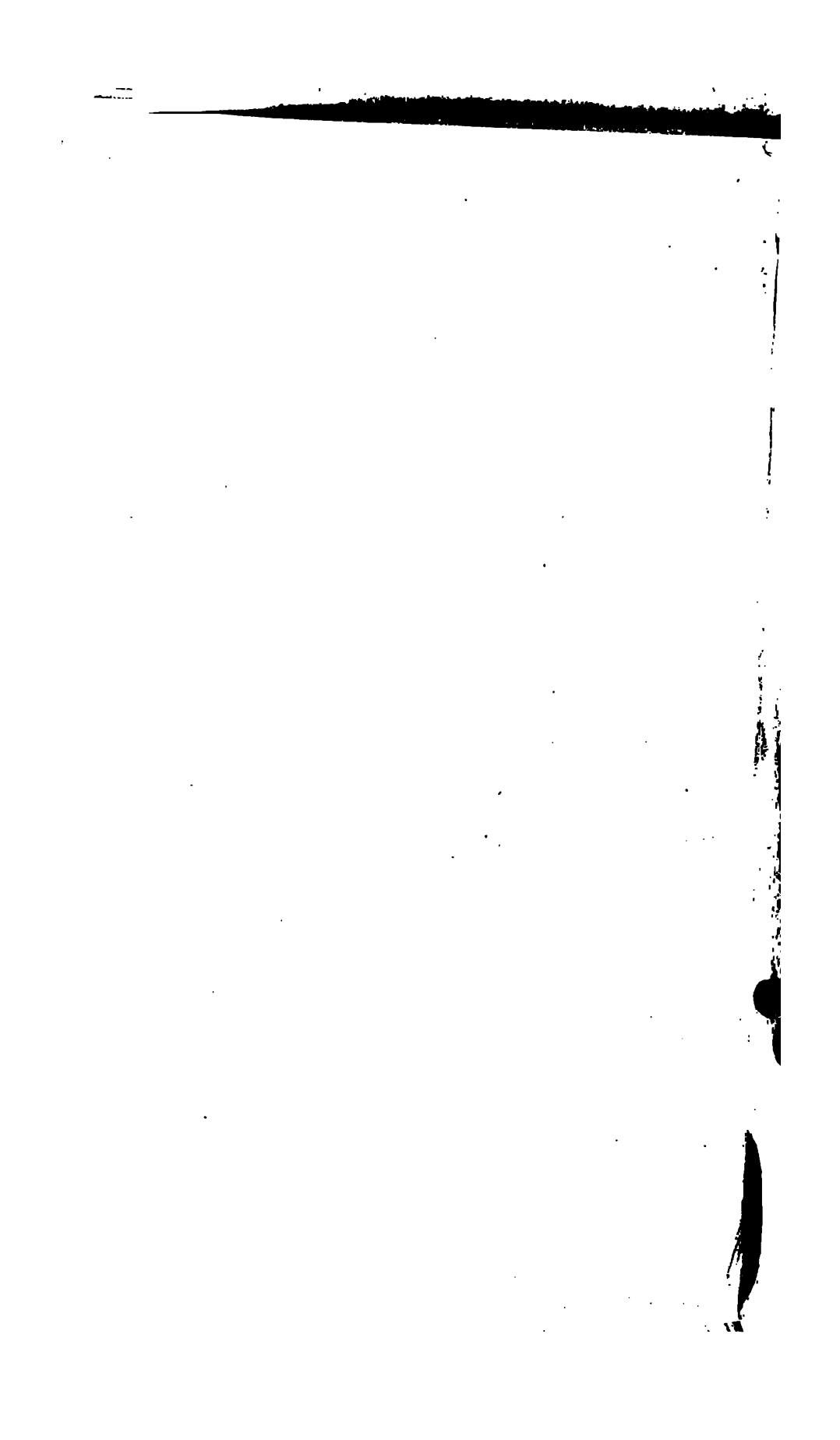
H. B. CORNWALL.

JOHN C. GREEN SCHOOL OF SCIENCE,
PRINCETON, N. J. Dec. 18, 1888.




RADE
0·00335


THREE MILES
BEECH


ONONDAGA
CREEK
RICHARDS
LAWTON
LA FAYETTE
BELDEN
PARK
COURT
PARK
AVE.
MIDLAND
AV. AND
KENNEDY
FULTON
CASTLE
THREE MILES
BEECH